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A report on the fisheries resources of the lower Nelson River and the impacts of hydroelectric development, 1989 data.

By Swanson, G.M., K.R. Kansas, S.M. Matkowski and P. Graveline

Manitoba
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Fisheries

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EXECUTIVE SUMMARY

In 1989, as in previous years, Fisheries Branch conducted studies relative to hydroelectric development in the lower Nelson River system. The purpose of these studies included understanding how fish populations use habitat within the Nelson River system, documenting stock conditions before and as impoundment occurs, and investigating potential mitigation or enhancement opportunities.

Use of the Limestone and Nelson rivers by adult brook trout was investigated further in 1989, specifically to determine what areas these fish inhabited during spring and summer. Adult brook trout were tagged with radio transmitters in the Limestone and Nelson rivers in late May and early June. Locations of these fish were monitored by aerial tracking through the following summer, fall and winter. In summer, the trout inhabited the mainstem Limestone and Nelson rivers, using habitat opportunistically and not undertaking any significant migrations. Monitoring in fall and winter revealed behaviour similar to that observed during earlier studies of large adult brook trout. In fall they migrated to areas near previously identified spawning sites, then after the spawning period, returned to rearing habitat. In winter most individuals remained near the areas where they had been during summer, in either the Limestone or Nelson rivers. A few may have migrated downstream in the Nelson River, perhaps as far as the Hudson Bay estuary.

Studies of lake sturgeon investigated use of the Angling Lake/River system and the Nelson River immediately downstream of

the Long Spruce Generating Station (L.S.G.S.). Netting for adult sturgeon indicated that limited spawning probably occurs below the L.S.G.S. An intensive sampling survey in Angling Lake and Angling River did not capture any young-of-the-year or juvenile sturgeon. If sturgeon spawn in that system it is most likely near the mouth of the Angling River, and newly hatched young probably drift downstream into the Nelson River. Radio telemetry studies provided further evidence that adult sturgeon use Angling Lake for extensive periods (months or years), occasionally emigrating downstream to overwinter in the Nelson River and perhaps spawning at the mouth of the Angling River enroute.

The long-term, brook trout monitoring projects initiated in past years were continued in 1989. Spawning populations were monitored in fall through operation of fish fences in spawning streams. In most streams, numbers of adults passing through these fences were similar to previous years. In Sky Pilot Creek the number captured increased dramatically, however this is not assumed to indicate a population increase. It may instead be the result of a change in habitat conditions upstream (e.g. fewer beaver ponds), allowing fewer fish to remain in the creek in fall than in previous years.

Larval brook trout were again monitored by means of drift samplers placed in several streams. Catch was comparable to previous years, and as in previous years, was influenced by discharge and location of the samplers in each stream. Samplers in small streams consistently collect larvae, while those in large streams are less efficient (i.e. sample a smaller portion of the

flow) and collect few if any larvae. A comparison of catch per unit of effort in fast verses slow areas of a stream cross section indicated that larval drift is not random across the width of a stream. These variations must be considered in comparisons of catch per unit effort between years in one stream, and between streams in the same year.

Electrofishing surveys of juvenile brook trout in tributaries of the Limestone and Conawapa forebays once more indicated that both spawning streams and smaller nursery-only streams serve as rearing habitat for young-of-the-year. As in previous years, spawning streams harboured greater numbers than the nursery-only streams.

The annual population estimate in CN Creek indicated that the number of rearing brook trout was half as large as it had been in 1987. As in 1988, the reason for this decrease was spring freezing and washout of the CN Creek road crossing. The washout deposited sediment in the stream thereby decreasing suitable fish rearing habitat and invertebrate food producing habitat.

Floy tag recaptures continued to illustrate that brook trout use habitat within the Nelson River system opportunistically, and may move between streams within the system.

Strontium analysis of fin rays indicated that less than one percent of adult brook trout sampled during monitoring were anadromous (had spent part of their life in the ocean). By the same analysis, 69% of a sample of brook trout from French Creek near Hudson Bay had strontium levels which would indicate an anadromous lifestyle.

Opportunities for mitigation or enhancement were investigated in the Kettle River system and the Conawapa Forebay in 1989. Streams with potential for incubating brook trout eggs, but which are not currently used as such, were surveyed for groundwater upwelling in the substrate. Groundwater upwelling appears to be necessary for successful incubation of brook trout embryos in the Nelson River system. Artificial incubation at groundwater sites may be used as a means of increasing brook trout populations. Only one area of groundwater upwelling was located in 9-Mile Hole Creek in the Kettle River system. Almost all streams investigated in the Conawapa Forebay contained at least one upwelling.

Artificial incubation was investigated by placing baskets of fertilized brook trout eggs at groundwater upwellings in 9-Mile Hole Creek and Beaver Creek. The eggs at Beaver Creek were recovered in March of 1990, none had developed or survived. The eggs at 9-Mile Hole Creek could not be recovered due to extreme ice conditions.

The transfer of adult brook trout to the Kettle River system continued in 1989, as an enhancement project aimed at rehabilitating stocks in the Kettle River system. Three of the 28 transferred trout were tagged with radio transmitters and monitored in the following months. These fish moved out of the Kettle River soon after stocking, and inhabited the Long Spruce Reservoir during fall and winter. Movements of these fish indicated that they were in good condition and reacting to seasonal habitat changes.

McMillan Lake in the headwaters of the Limestone River system was examined in 1989 to determine its importance to brook trout and

the potential for enhancement. Although Gaboury (1980) had captured both brook trout and northern pike in McMillan Lake previously, only northern pike were present in 1989. It is likely that the lake winterkills occasionally and fish repopulate the lake by migrating in from McMillan Creek over a large beaver dam. Enhancement of McMillan Lake for brook trout rearing is possible, but would be very costly and have uncertain benefits to the Limestone River system.

During this and previous years of research in the Nelson River system, data have been collected on other species during studies of brook trout and lake sturgeon, and in some of those studies (electrofishing and fish fences) were not included in reports. These data have been summarized and included as an appendix in this report. Years included are 1987-89. Data which have been included in previous reports are not included in this appendix. Other species collected in 1985 were reported in Swanson (1986). Data on other species collected during studies of the Long Spruce Reservoir in 1986 were presented in Swanson and Kansas (1987). Data on other species collected during gill netting of the mainstem Nelson River in 1987 and 1988 were reported in Swanson et al. (1988) and Swanson et al. (1990), respectively.

ACKNOWLEDGEMENTS

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PART I

MCMILLAN LAKE INVENTORY

PART I

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INTRODUCTION

The contribution of headwater lakes to the Limestone River and its tributaries, in terms of brook trout overwintering habitat, is not well known. Overwintering habitat is a critical seasonal requirement for brook trout and is believed to be in short supply in the Limestone River system. Gaboury (1980) found adult brook trout in one such headwater lake, McMillan Lake. Swanson et al. (1990) found adult and young-of-the-year brook trout in McMillan Creek which flows out of McMillan Lake and into the Limestone River (Figure 1).

To increase the knowledge of brook trout biology in the area and the responses of headwater trout populations to hydroelectric development, a fisheries investigation was initiated on McMillan Lake. The study also investigated the suitability of McMillan Lake for stock enhancement activities.

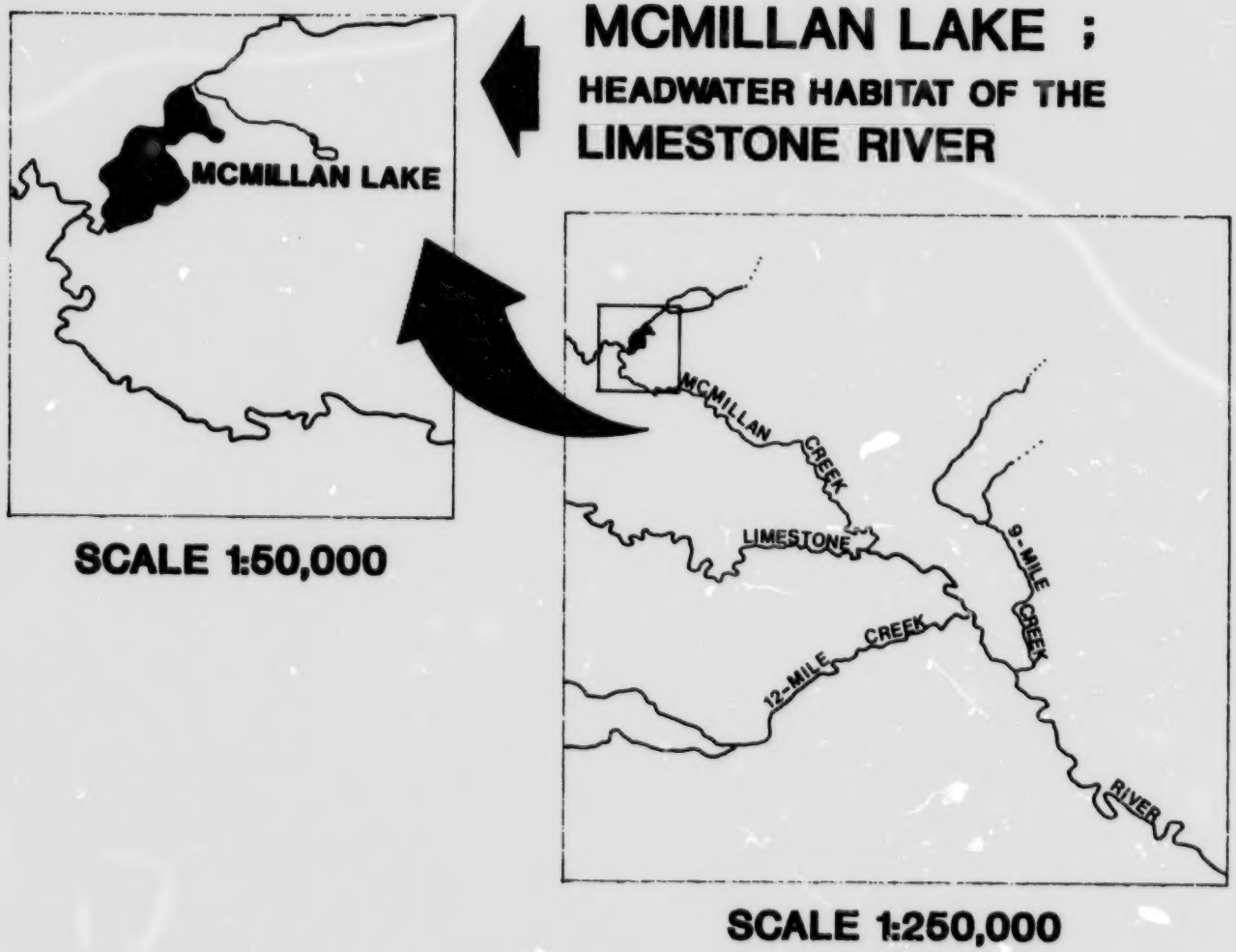

Fig. 1. Study area.

METHODS

Between August 4 and 9, 1989 physical and biological investigations were conducted on McMillan Lake. Three gill net gangs, consisting of one pannel each of mesh sizes 3.8, 5.1, 7.6 and 9.5 cm (stretch measure), were used to capture fish. Individual pannels were 22.9 m long and 1.8 m deep; entire gangs were therefore 91.6 m long. Nets were set at random locations to sample as much of the lake as possible (Figure 2), and were in place overnight for at least 20 hours. Angling was also used as a means of sampling large fish. Fish caught were sampled for length, weight, stomach contents, sex and age.

A 15 m x 1.5 m beach seine was used to sample forage species and young-of-the-year. The seine was used along the shoreline where water was shallow enough to allow it to be used effectively (Figure 2).

Two one-litre samples of surface water were collected, packed in ice, and shipped to the lab within 24 hours (Figure 2). They were analysed by the Environmental Management Division of the Department of Environment.

A Furano FG 200 MK3 sonar unit was used to depth sound McMillan Lake in order to construct a bathymetric map.

The location and extent of emergent aquatic vegetation was recorded on a map of the lake. General observations of inflow/outflow characteristics, beaver activity, human use, etc. were recorded.

On February 14, 1990, 90 m of 7.6 cm gill net (stretch

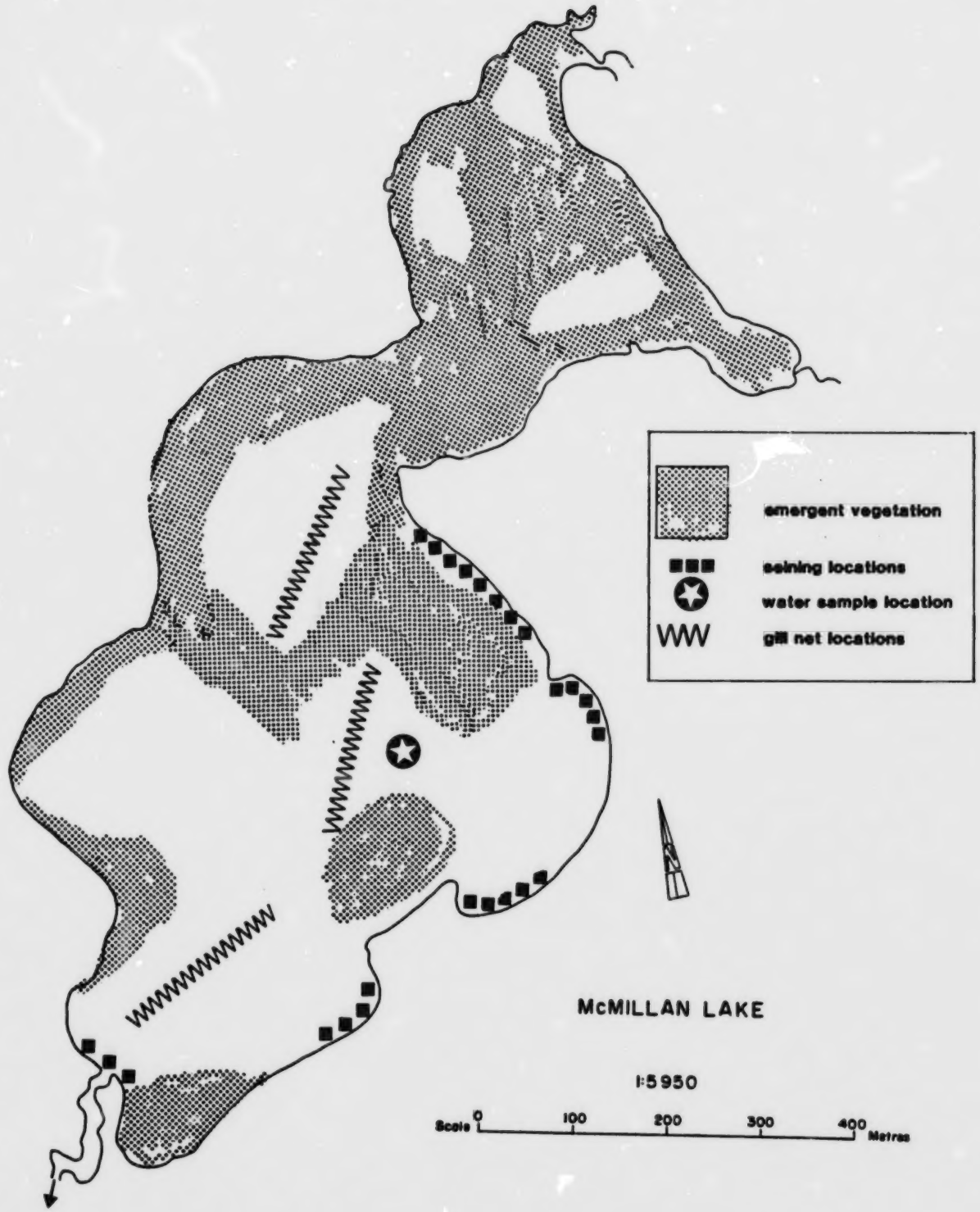

Fig. 2. Summer sampling locations and distribution of emergent vegetation within McMillan Lake.

measure) was set under the ice in McMillan Lake. On February 16 the gill net was removed. At that time dissolved oxygen tests were attempted, but were precluded by freezing rain which necessitated immediate return of the helicopter.

Table 1. Gill net catch summary for northern pike sampled in McMillan Lake, August, 1989.

Mesh Size (cm)	Mean Length (mm)	Mean Weight (gm)	Mean Age	Total #
3.8	426	700	2.0	2
5.1	512	971	4.0	7
7.6	511	989	3.9	14
9.5	563	1288	4.5	8

Table 2. Age-specific mean fork lengths and weights for northern pike from McMillan Lake, August, 1989.

Age	Number	Frequency %	Mean Length	Mean Weight
1	2	4.5	342	550
2	4	9.1	442	713
3	10	22.7	519	1005
4	11	25.1	543	1109
5	12	27.3	553	1282
6	3	6.8	573	1367
7	2	4.5	573	1175
8	--	--	--	--
9	--	--	--	--
10	--	--	--	--
Total Mean	44	100	524	1052

Table 3. Chemical analyses of water sampled from McMillan Lake in 1989 compared to samples taken in 1979.

Chemical Parameter	McMillan Lake July 10/1979	McMillan Lake Aug. 8/1989
pH	8.2	7.9
Conductivity (umho/cm)	215	291
Total hardness (mg/l)	115	155
Ca (Ext.) (mg/l)	31	42.5
Mg (Ext.) (mg/l)	9	11.9
Na (Ext.) (mg/l)	10	3.83
Fe (Ext.) (mg/l)	0.29	0.02

RESULTS

The three gill nets set during August, 1989 yielded 31 northern pike (Esox lucius). The mean length and weight, average age and number of pike caught in the four different mesh sizes is presented in Table 1. Angling yielded another 13 pike. No brook trout were captured by either method. The gill nets set in February of 1990 yielded no fish.

Figure 3 shows the age frequency distribution of the 44 pike captured in August, 1989; Table 2 shows age-specific mean fork lengths and weights.

Stomach contents revealed that 84.1% of the pike had eaten 5-100 freshwater shrimp (Gammorus sp.) and 15.9% had empty stomachs. Eight pike had eaten molluscs and one had a leech in its stomach. Twenty-six were males and 18 were females.

Seining produced no fish. The only invertebrate species caught of appreciable size were freshwater shrimp. The average seine haul yielded 2-3 litres of shrimp.

Chemical characteristics of water samples collected from McMillan Lake in August, 1989 were very similar to those collected in 1979 (Gaboury 1980) (Table 3). Conductivity, pH, hardness and ion concentrations were also very similar to those of the Limestone River on July 10, 1988 (Swanson et al. 1990).

The contour map of McMillan Lake, which was generated from the depth sounding data, is presented in Figure 4. Contours are in 2 meter intervals. The area of the lake which was covered by emergent vegetation, primarily yellow water lilies (Nuphar sp.), is

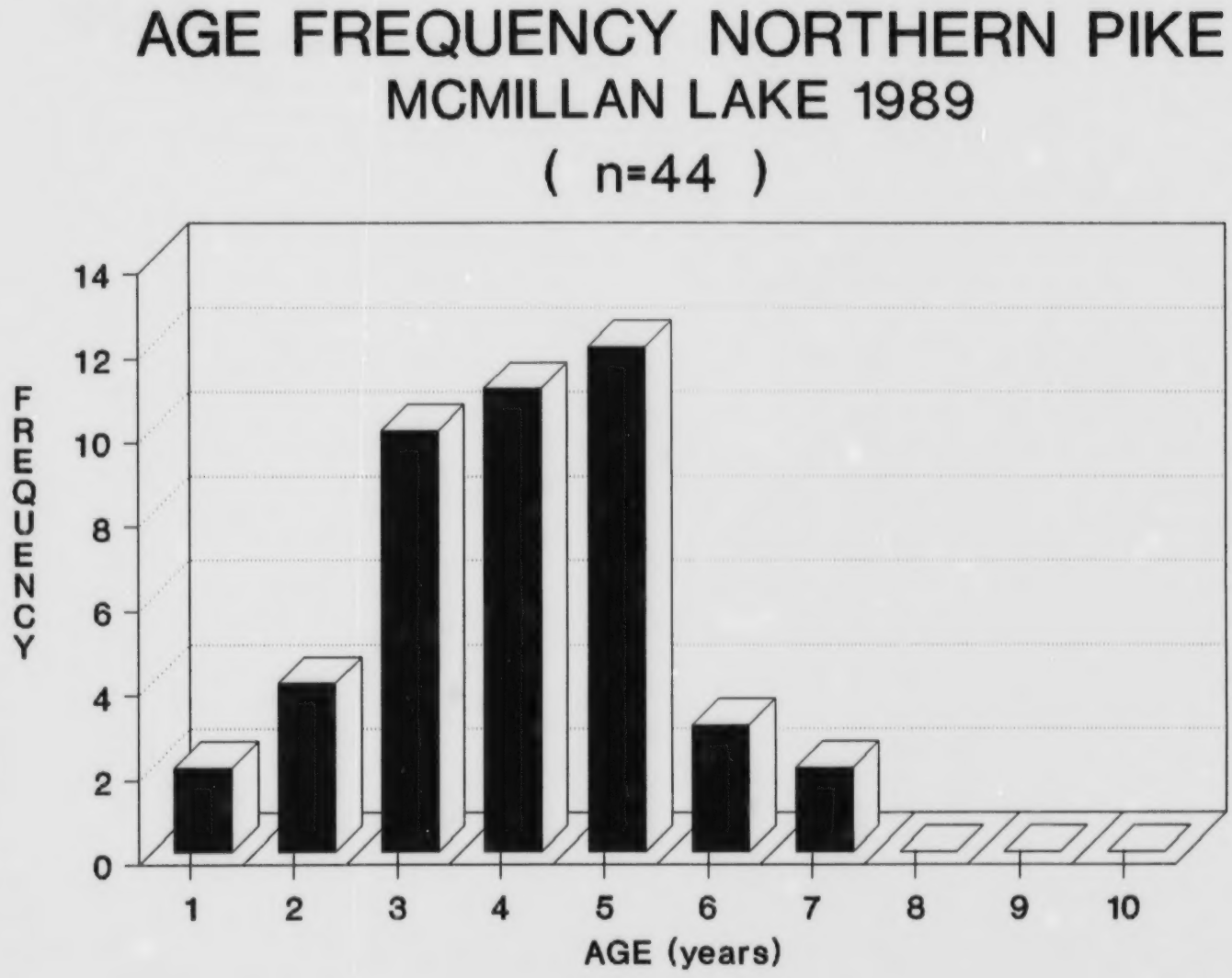

Fig. 3. Age frequency distribution of northern pike caught in McMillan Lake in August, 1989.

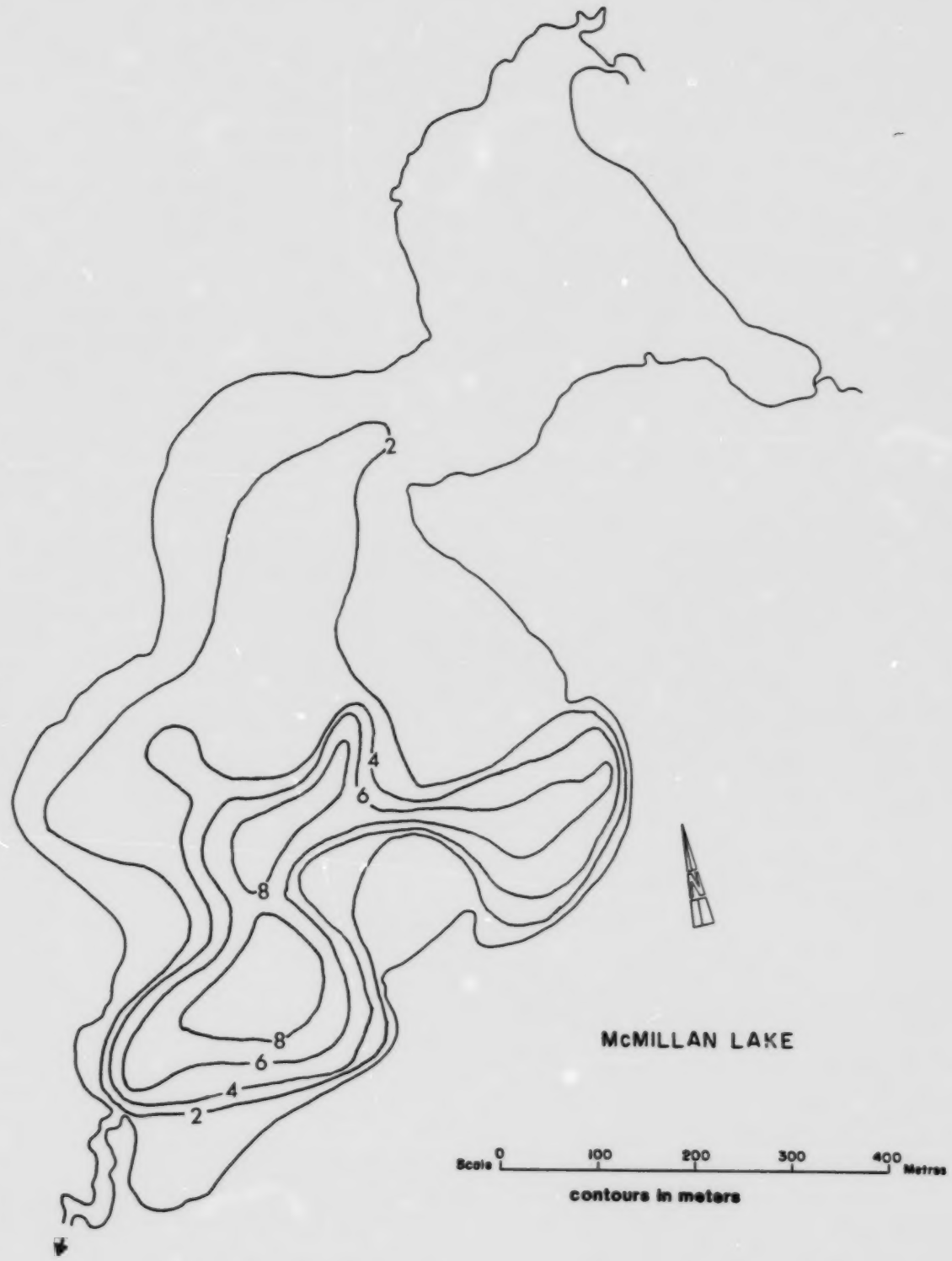

Fig. 4. Contour map of McMillan Lake.

illustrated in Figure 2. The outflow of McMillan Lake is obstructed by a beaver dam approximately 110 cm high. A small amount of water was trickling through it during August, 1989. Small northern pike, 200-230 mm in length, were observed and angled in the area below the beaver dam. Three beaver lodges are located on the lake, however no beavers were seen. There is also a trapper cabin on the lake.

DISCUSSION

McMillan Lake appears suitable for brook trout overwintering, having an adequate food supply, (Gammorus sp.), size and depth. However, only pike were captured during the summer netting program. Gaboury (1980) found both brook trout and pike inhabiting McMillan Lake with pike occurring in greater numbers. He also reports that the lake appears suitable for overwintering because of the deep southwest portion.

Based on 1989 results, McMillan Lake offers questionable overwintering habitat. The large number of pike in the lake would probably feed heavily on any small brook trout migrating in from McMillan Creek. Since mainly freshwater shrimp were found in pike stomachs, and no forage fish were captured, it is unlikely that young brook trout would survive to rear in McMillan Lake. With approximately 50% of the lake occupied by aquatic vegetation, winterkill seems likely if heavy snow cover limits sunlight into the lake. Winter gill netting which yielded no fish supports this statement, however the lack of dissolved oxygen data limits conclusions.

The presence of a few adult brook trout in McMillan Lake in 1979 (Gaboury 1980) but none during this study suggests that brook trout may inhabit headwater lakes on an opportunistic basis. Physical conditions must be suitable, and competition by pike should be minimal.

The beaver dam which was present at the outflow of McMillan Lake during both 1979 and 1989 studies, prevents fish migration

during all seasons except spring. Fish can only enter or leave McMillan Lake in the spring, when water levels are at their highest. If brook trout moved into McMillan Lake following winterkill of pike, and were subsequently trapped due to summer water levels, they would probably thrive on the freshwater shrimp as long as the lake did not winterkill. Unfortunately, even if such a scenario did occur, it is likely that pike would also enter the lake and compete for the limited food supply.

Enhancement of McMillan Lake for brook trout would include two phases. First, if a complete winterkill has not occurred, pike would have to be removed. This can be done through chemical reclamation using 5% emulsifiable rotenone, or by an extensive gill netting program. After eliminating the pike, brook trout would have to be stocked. As well, a structure would have to be built in addition to the beaver dam to stop pike from re-entering the lake in spring.

These enhancement activities would be expensive. For example, the amount of rotentone necessary to eliminate pike from a lake the size of McMillan Lake (area and mean depth) would cost $10,000 (Hugh Valiant, Manitoba Fisheries Branch, pers. comm.). Because of such expenses, the relative isolation of McMillan Lake, and the possibility of winterkill the authors feel that enhancing McMillan Lake to increase brook trout stocks within the Limestone River area is not a worthwhile endeavour.

CONCLUSIONS

1. Only pike inhabited McMillan Lake in August of 1989. They fed primarily on freshwater shrimp.

2. No fish were captured during gill netting in March of 1990. However, winterkill can not be concluded since dissolved oxygen tests were not completed.

3. Due to the large beaver dam at the outflow of McMillan Lake, fish can only migrate in during spring freshet.

4. Enhancement of McMillan Lake for brook trout rearing would be too costly and have uncertain benefits to the Limestone River system.

RECOMMENDATIONS

1. Enhancement of McMillan Lake should not be pursued as a mitigation opportunity for Limestone River brook trout stocks.

2. Other headwater lakes should be studied to gain a better understanding of this habitat and its importance to Limestone River brook trout stocks.

PART II

GROUNDWATER SURVEYS

PART II

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INTRODUCTION

It may be possible to enhance brook trout stocks, or mitigate impacts in the lower Nelson River system, through incubation of eggs in streams not currently used for spawning. Streams such as those along the north shore of the Conawapa Forebay are currently underutilized as nursery habitat for brook trout fry. Brook trout do not spawn in these streams. However, some fry from the Limestone River system drift into the Nelson River, then migrate upstream into the Conawapa Forebay streams. The number of fry available for migration upstream from the Nelson River may be limited by low populations of spawners in the Limestone River system.

Streams in the Kettle River system have only remnant brook trout populations due to overfishing and habitat degradation. There are several historical spawning locations in the Kettle River system at which spawning is minimal or no longer occurs.

The probability of successful incubation of brook trout eggs in tributaries to the Conawapa Forebay, or in the Kettle River system, will depend to some degree on availability of groundwater upwellings in the substrate. Groundwater upwelling in streams of the Nelson River system appears to be essential for successful incubation of brook trout eggs. All spawning sites identified to date have been located at areas of groundwater upwelling.

Groundwater upwelling is necessary because of the fine sediment which constitutes much of the stream substrate in this region, and also because of the severe winters which may freeze

streams entirely where no groundwater upwelling occurs. Fine sediments prevent penetration of surface water through the substrate. Surface water travelling within the substrate generally provides oxygen to, and removes metabolic wastes from, incubating salmonid embryos (Coble 1961; Hausle and Coble 1976; Chapman 1988). As little as 20% fines or sand in substrate has been found to reduce surface water penetration and survival of brook trout embryos (Hausle and Coble 1976). However, in areas of fine substrate where groundwater upwelling occurs, salmonid eggs often successfully develop and hatch (Webster 1962; Sowden and Power 1985). This is especially true of brook trout, which have been known to prefer fine substrate with groundwater upwelling over clean coarse substrate without groundwater upwelling (Webster 1962).

As a first step in assessing the utility of tributaries to the Conawapa Forebay and Kettle River for incubating brook trout eggs, several streams were intensively surveyed in 1989 for the presence of groundwater upwellings.

METHODS

The seven streams included in this study were Beaver, Swift, Goose, Tiny, 9-Mile Hole and 15 creeks, plus an unnamed stream dubbed "Raindance Creek". All of these streams, with the exception of 9-Mile Hole Creek, are located along the north shore of the Conawapa Forebay (Figure 1). Nine-Mile Hole Creek is a tributary of the Kettle River (Figure 1).

In the summer of 1989, each of these streams was surveyed on foot by two persons. The area surveyed extended from the mouth upstream to habitat which was no longer suitable for spawning. Habitat characteristically changes from steep gradient with clean substrate in the downstream portions, to low gradient with macrophytes, algae and detritus further upstream. Temperature of surface water was measured using a hand-held mercury thermometer at intervals of approximately 200 m in each stream. At intervals of approximately 10-20 m intrasubstrate temperature was measured using a Fluke model 51 electronic thermometer with a 24 inch K-type thermocouple encased in stainless steel. The thermometer was inserted approximately 20 cm into the substrate for temperature measurement. Sites where intrasubstrate temperature was notably lower than ambient stream temperature were more intensively surveyed to locate the coldest area. Each potential groundwater area was recorded on a map along with lowest intrasubstrate temperature measured, and substrate composition at that site.

In assessing presence of groundwater at recorded sites, intrasubstrate temperatures of 6 °C or lower were considered

Figure 1. Locations of streams surveyed for groundwater upwelling, 1989.

indications of significant upwelling.

RESULTS AND DISCUSSION

Only one area of groundwater upwelling was located in 9-Mile Hole Creek. It was near the confluence with the Kettle River (Figure 2), immediately downstream of a large beaver dam. Ambient temperature of the surface water at this site was 22 °C, while the intrasubstrate temperature was 5.7 °C (Table 1). Substrate consisted primarily of uncompacted gravel with silt in surrounding areas.

Raindance Creek, the tributary closest to the mouth of the Limestone River, contained no groundwater upwellings (Figure 2). The ambient water temperature when surveyed on July 21 was approximately 16 °C. Only one site with notably lower intrasubstrate water temperature (11.6 °C) was found, however this decrease was not considered sufficient to indicate groundwater upwelling. The streambed of Raindance Creek contained large amounts of silt, especially downstream of the road crossing. Cobble and boulder were often apparent under this layer. Upstream of the road crossing siltation was less noticeable with cobble and boulder comprising most of the substrate. No habitat suitable for brook trout egg incubation was identified in Raindance Creek.

Two areas of significant groundwater upwelling were identified in Beaver Creek (Figure 3). The upstream area (# 2, Table 1) had an intrasubstrate temperature of only 3 °C, and primarily gravel substrate. This site appeared suitable for incubation of brook trout eggs. The downstream site had a higher intrasubstrate temperature and the streambed was composed of cobble and boulder.

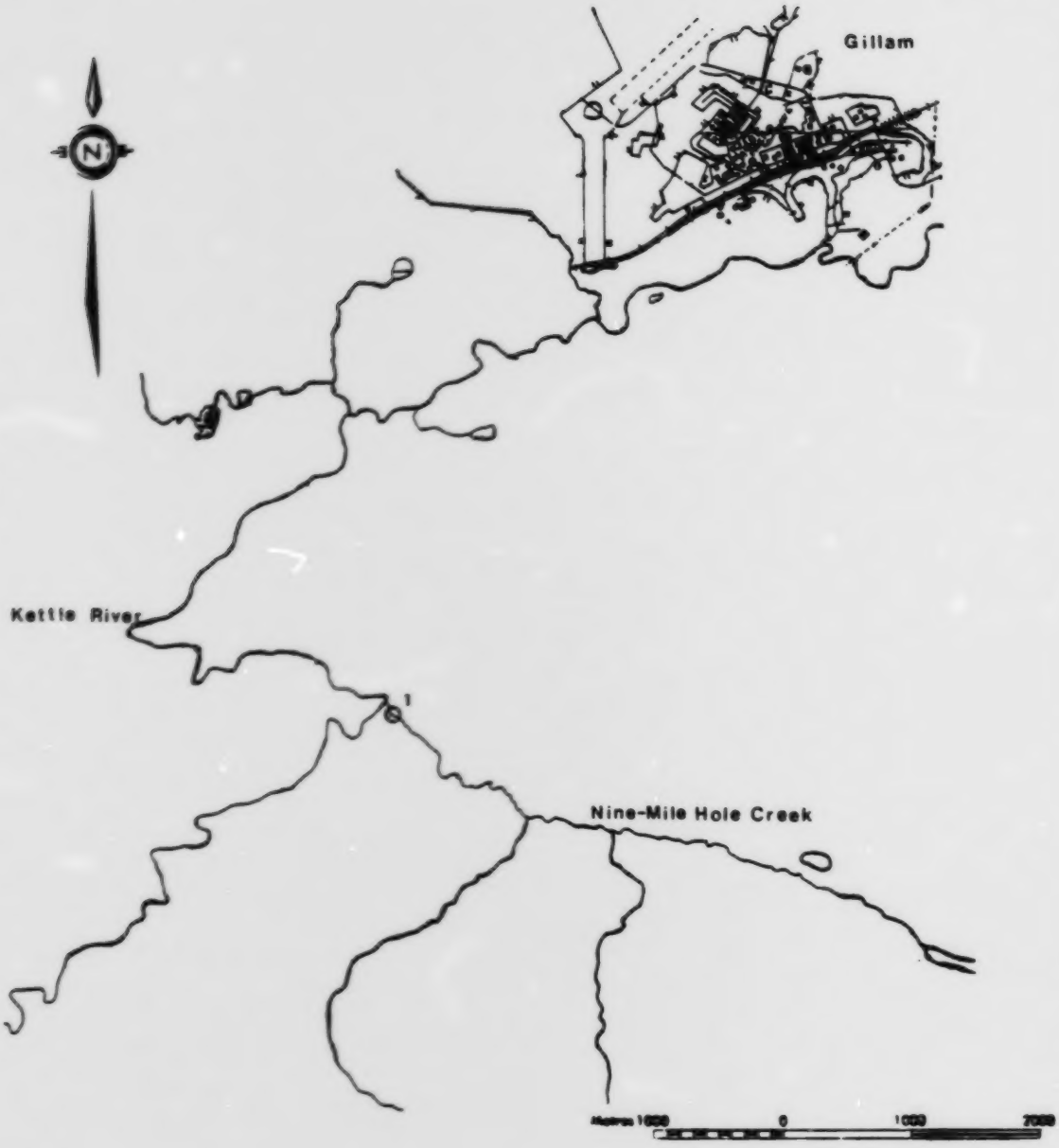

Figure 2. Location of groundwater upwelling site on Nine-Mile Hole Creek, 1989.

Table 1. Characteristics of groundwater sites on study streams, 1989.

Stream	Date	Groundwater Site	Temperature (°C)		Substrate[a] Composition
			Ambient	Intrasubstrate	
9-Mile Hole Ck.	July 20	1	22.0	5.7	80% Gr, 20% Si
Beaver Ck.	July 28	1	15.0	5.9	25% Bd, 75% Co
		2	14.0	3.0	80% Gr, 10% Sa, 10% Si
Swift Ck.	July 27	1	14.0	3.1	70% Co, 30% Gr
Tiny Ck.	July 27	1	13.0	2.2	20% Bd, 40% Gr, 30% Sa, 10% Si
		2	13.0	5.5	80% Bd, 5% Gr, 10% Sa, 5% Si
		3	14.0	5.6	90% Bd, 10% Si
Goose Ck.	July 26	1	16.0	6.0	50% Bd, 50% Co
		2	16.0	3.7	50% Bd, 45% Co, 5% Sa
15 Ck.	July 28	1	13.0	5.6	50% Bd, 30% Co, 20% Gr
		2	13.0	5.6	40% Co, 40% Sa, 20% Si

a - Si = silt, Sa = sand, Gr = gravel, Co = cobble, Bd = boulder

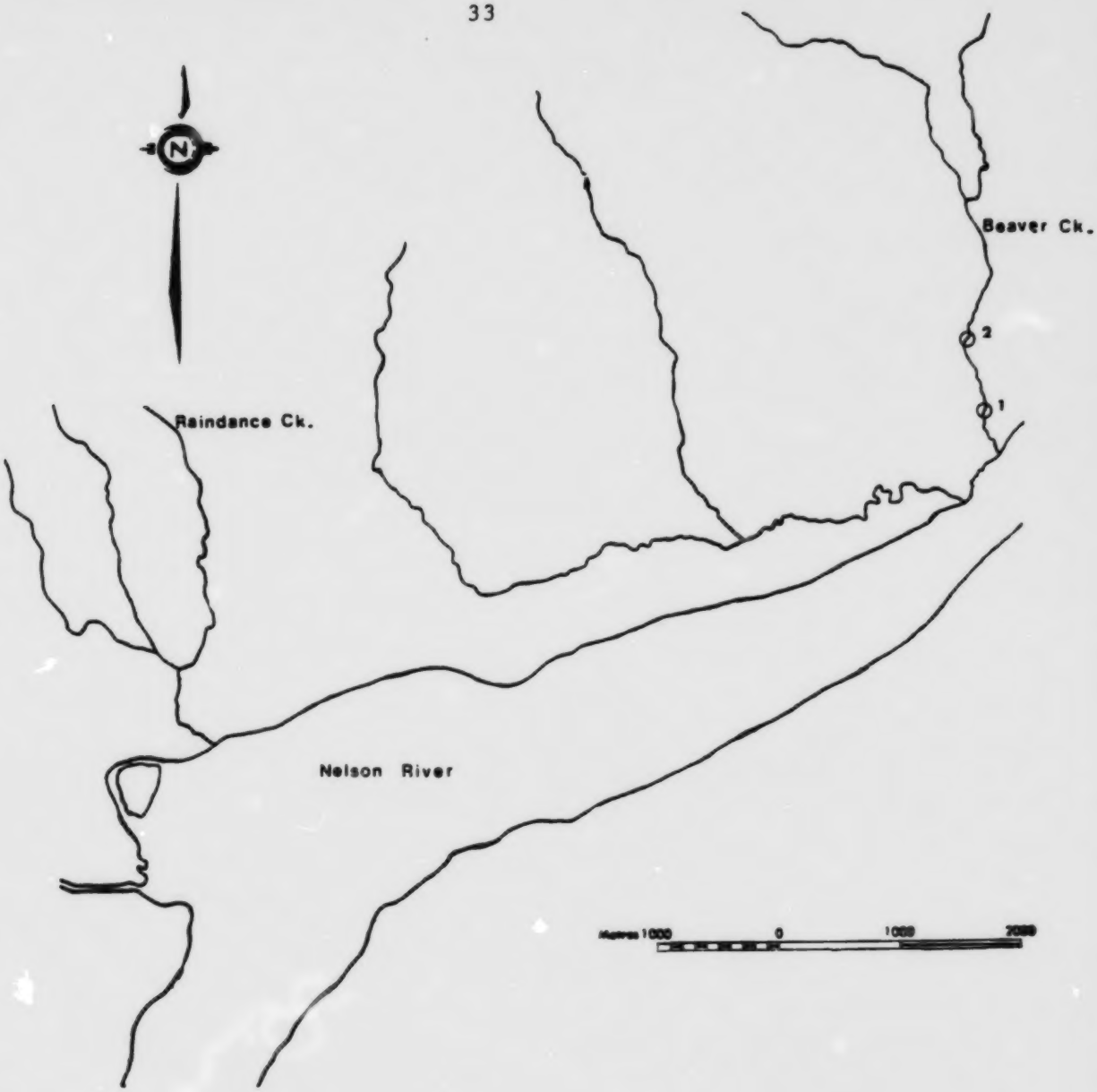

Figure 3. Locations of groundwater upwelling sites on Beaver Creek, 1989.

The large substrate rendered this location unsuitable for incubation of brook trout eggs.

In Swift Creek, only one area of significant groundwater upwelling was located (Figure 4). At this site on July 27, the ambient surface water temperature was 14 °C while the intrasubstrate temperature was 3.1 °C. Substrate at this site is not ideal for brook trout egg incubation as it is largely composed of cobble (Table 1).

Three groundwater areas were identified in Tiny Creek, all within 1 km of the mouth (Figure 4). The most upstream site (#1, Table 1) was most suitable for brook trout egg incubation; intrasubstrate temperature was 2.2 °C and substrate was primarily gravel and sand. The two downstream sites were less suitable, both had substrate composed largely of boulders, and warmer intrasubstrate temperatures which may indicate less vigorous groundwater upwelling (Table 1).

In Goose Creek two groundwater areas were identified. As in Tiny Creek, both were located in the downstream portion of the stream (Figure 4). Both sites had ambient surface water temperatures of 16 °C; intrasubstrate temperature was much lower at the upstream site, than at the downstream site (Table 1). Unfortunately, substrate at both sites was almost entirely boulder and cobble which would be difficult to incubate eggs in.

Fifteen Creek also contained two groundwater sites (Figure 4, Table 1). Substrate at the upstream site was composed of cobble, sand and silt, and could possibly be used for egg incubation. Substrate at the downstream site was too coarse to be used for egg

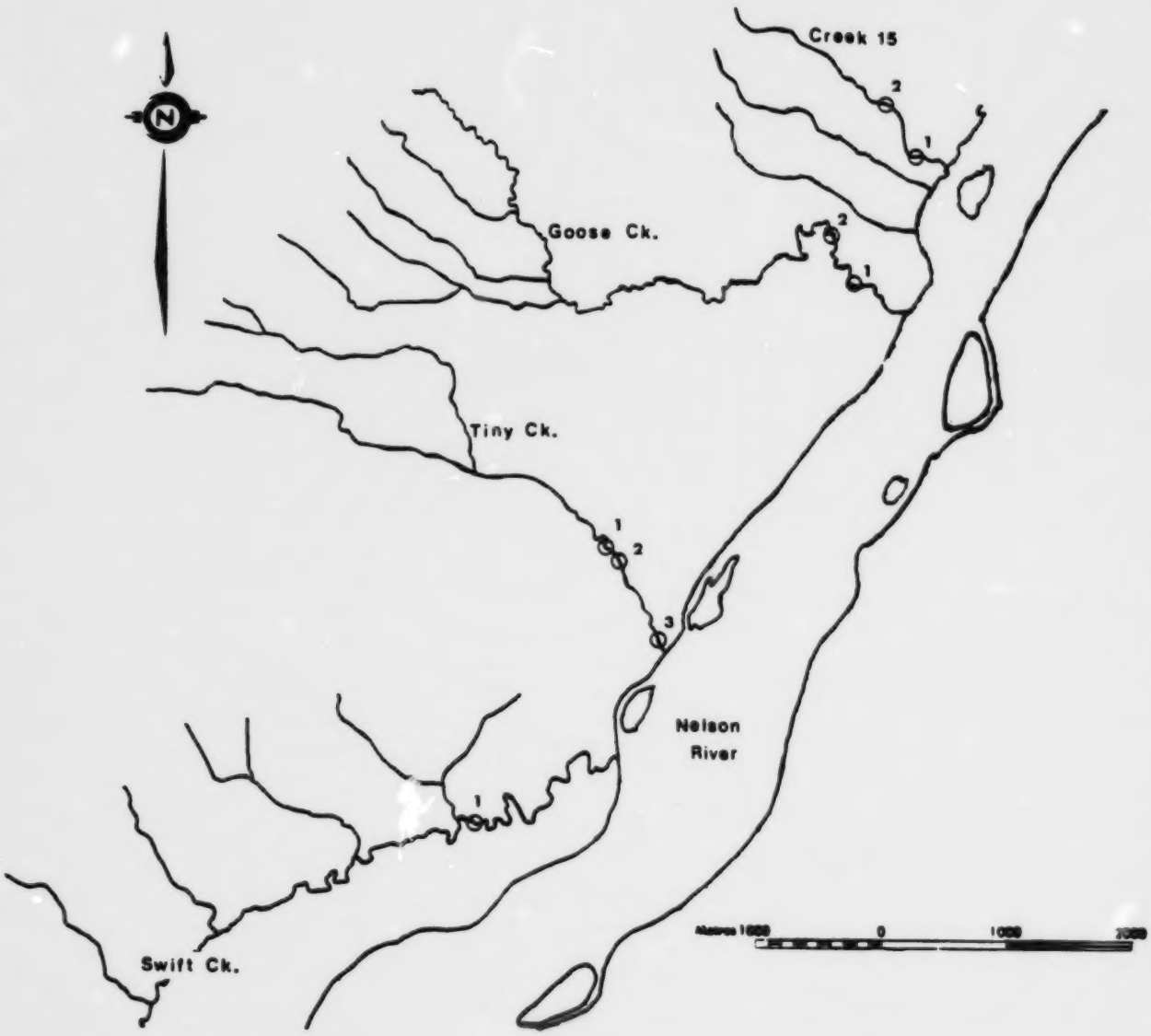

Figure 4. Locations of groundwater upwelling sites on Swift, Tiny, Goose and 15-Mile creeks, 1989.

incubation.

The streams in the Conawapa Forebay have some potential for incubation of brook trout eggs. Upwelling groundwater was located in all but one of the study streams. Those streams which contained more than one groundwater upwelling appear to be more suitable at the farthest upstream sites than downstream. The upstream sites generally exhibited cooler intrasubstrate temperatures, which likely indicate greater groundwater upwelling and therefore would provide better flow past eggs. As well, substrate at these sites is more suitable than at downstream sites where it tends to be coarse.

CONCLUSIONS

1. Tributaries along the north shore of the Conawapa Forebay have some potential for incubation of brook trout eggs. Upwelling groundwater was detected in all study streams except Raindance Creek. Suitable substrate for burying baskets of eggs is present at the most upstream sites in these streams.

2. One area of groundwater upwelling was located in 9-Mile Hole Creek. This site also contained substrate of suitable size and low compaction.

3. The presence of upwelling groundwater and suitable substrate does not ensure that incubation will be possible at such sites. Upwelling must be sufficient to provide adequate exchange of oxygen and metabolic wastes with eggs, and prevent freezing in winter. The necessary rate of flow will vary with substrate composition and compaction and is unknown.

RECOMMENDATIONS

1. Studies should be undertaken to determine the rate of upwelling at known spawning sites, as well as at the site on CN Creek where eggs were successfully incubated in 1988-89. These data may be used to judge whether flow at potential incubation sites may be suitable, and whether trial incubation should be attempted.

2. Historical spawning sites in the Kettle River system should be surveyed for upwelling groundwater to determine the current potential for egg incubation, and perhaps reintroduction of spawning.

PART III

BROOK TROUT SPAWNING ENHANCEMENT

PART III

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INTRODUCTION

It has become apparent from previous studies, that reproduction of brook trout in the lower Nelson River system is limited by the requirement for very specific habitat conditions. The presence of ample upwelling groundwater at spawning sites appears to be essential for development of embryos and emergence of fry.

Streambeds within the lower Nelson River system contain large proportions of fine particles, which characteristically inhibit flow of water through substrate (Hausle and Coble 1976; Sowden and Power 1985; Chapman 1988). Flow through the substrate is necessary to provide incubating eggs with oxygen and to remove metabolic wastes (Coble 1961; Sowden and Power 1985). In other regions, as well as the Nelson River system, it has been found that where fine substrate occurs, groundwater upwelling may provide adequate flow to allow salmonid embryo development (Webster 1962; Sowden and Power 1985; Swanson et al. 1990). Fine particles may also act as a physical barrier to emerging fry (Phillips et al. 1975; Hausle and Coble 1976). It is possible that groundwater upwelling in the Nelson River system also serves to loosen fine substrate allowing fry to emerge (Swanson et al. 1990).

Since brook trout reproduction is limited to particular areas in the Nelson River system, it may be possible to enhance stocks by identifying suitable spawning sites in areas currently not utilized, and incubating brook trout eggs in those areas. The resultant fry would have previously underutilized habitat available

for rearing; their survival would increase brook trout production in the system. It is also possible that these fry could establish new self-propagating populations.

One area where spawning does not occur is along the north shore of the Nelson River in the Conawapa Forebay, in small streams such as Beaver Creek. Groundwater upwellings and appropriate substrate have recently been identified in these tributaries. A second area with potential for enhancement is the Kettle River system, which contains severely depleted brook trout stocks.

To investigate the possibility of enhancing brook trout populations in these two areas, fertilized eggs were artificially buried in Beaver Creek and 9-Mile Hole Creek at locations where groundwater upwelling occurs.

METHODS

The two streams in which brook trout eggs were artificially buried in 1989 were Beaver Creek in the Conawapa Forebay and 9-Mile Hole Creek at the confluence with the Kettle River. Incubation sites were chosen at previously identified areas of groundwater upwelling where substrate was of suitable size and loosely compacted (Figure 1).

Brook trout eggs were collected and fertilized from spawners captured by angling in the Weir River on September 21, 1989. All fertilized eggs were pooled before samples were removed. Immediately following fertilization, 400 eggs were placed in each of nine closed incubation baskets. The baskets, 9 cm in diameter and 10 cm high, were constructed of plastic mesh which allowed flow of water but prevented escape of eggs or fry. The bottom of each basket was lined with a layer of fine gravel, followed by a layer of coarse gravel, as described in Harris (1973). The eggs were then added and covered to the top of the basket with mixed gravel (Harris 1973). Lids were attached securely. The baskets were placed in a picnic cooler filled with water and transported by helicopter to CN Creek. They were removed from the cooler and placed in CN Creek for the night.

On the following morning, September 22, 1989, the baskets were placed in a picnic cooler of water and transferred by helicopter to Beaver Creek. Four holes were dug at the study site, each within 0.5 m of the others, and deep enough to accommodate a basket. A wooden stake was embedded on the downstream edge of each hole and

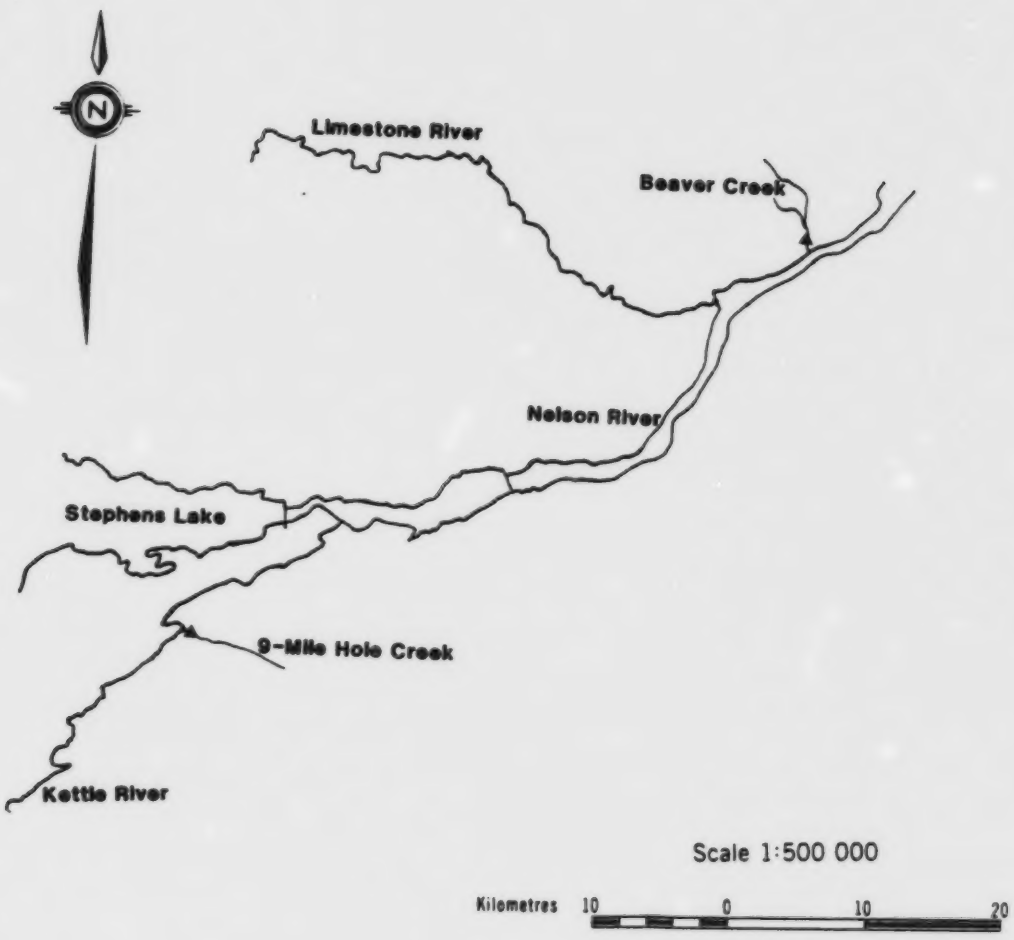

Figure 1. Locations of egg baskets (indicated as triangles) in Beaver Creek and 9-Mile Hole Creek, 1989-90.

marked with flagging tape. One basket was placed in each hole and covered to a depth of 5 cm with previously removed substrate.

Following basket placement in Beaver Creek, the remaining five baskets were transferred by helicopter to 9-Mile Hole Creek at the confluence with the Kettle River. The incubation site was located approximately 50 m upstream of the confluence and immediately downstream of a large beaver dam. Four baskets were buried and marked as described for Beaver Creek.

The remaining egg basket was packed in an insulated plastic bag and shipped by air cargo to Winnipeg. Upon arrival in Winnipeg, the sample was cleared with 10% acetic acid and examined by microscope to determine what percentage of the sample was fertilized.

The incubation site on Beaver Creek was visited on December 7, 1989 to record snowcover and ice conditions. The incubation site on 9-Mile Hole Creek was similarly visited on December 8, 1989.

Mid-March was chosen as appropriate for basket removal since, in the previous incubation study, calculation of Daily Temperature Units for incubation of eggs from fall of 1988 to March 14, 1989 determined that more than sufficient time had elapsed to hatch brook trout eggs (Swanson et al. 1990). Baskets were removed from Beaver Creek on March 13, 1990. Physical conditions were first measured and recorded, including snow cover, ice cover, water depth, substrate composition at basket sites, and surface and intrasubstrate temperatures. Surface temperatures were measured using a hand-held mercury thermometer while intrasubstrate temperatures were measured using a Fluke model 51 electronic

thermometer with a 24 inch K-type thermocouple encased in stainless steel. Dissolved oxygen in surface water was measured using a HACH Dissolved Oxygen Kit accurate to within 1 mg/l. Each basket was carefully removed from the substrate and placed intact in a plastic bag and cooler. The baskets were transported by helicopter to the Natural Resources Office in Sundance where they remained in the cooler for four hours until examined for the presence of eggs or fry.

The incubation site on 9-Mile Hole Creek was also visited on March 13, 1990, and an attempt was made to remove the egg baskets. The site had been noticeably altered by flooding and icing-over (>0.5 m of additional ice since December). No stakes or flagging tape were visible. Holes were chopped in the ice in an attempt to locate the baskets. A trench was also dug using a chain saw, however the baskets could not be located.

RESULTS AND DISCUSSION

Physical conditions observed at the two incubation sites in December of 1989 were notably different from conditions at the time of basket removal in March of 1990. There was little snowcover at the Beaver Creek site on December 7, and ice cover was very thin. The area immediately upstream of the incubation site was ice free. The incubation site on 9-Mile Hole Creek, when visited on December 8, had been flooded and ice had built up to a depth of approximately 0.5 m above the September water level. Approximately 5 cm of snow covered the ice at this site. The stakes and flagging tape were no longer visible. Flowing water was heard during the December visit, probably as it spilled over the beaver dam 3 m upstream.

Physical and chemical parameters recorded on March 13, 1990, when baskets were removed, are presented in Table 1. The Beaver Creek site was completely iced over, including the riffle area immediately upstream. A thin layer of fine detritus covered the substrate; average substrate composition was estimated as 10% fines, 60% sand, 20% small gravel and 10% large gravel. The surface water temperature was 0.4 °C and the intrasubstrate temperature at the centre of the site was 5.8 °C. Dissolved oxygen of the surface sample was 1.0 mg/l. There was no visible flow. Some scouring must have occurred since the eggs had been buried; all baskets were exposed and projecting above the substrate between 1 and 3.5 cm.

Physical characteristics at the 9-Mile Hole site were measured

Table 1. Physical characteristics at incubation sites, March 13, 1990.

Basket Site	Snow Depth (cm)	Ice Depth (cm)	Water Depth (cm)	Substrate[a] Composition	Intrasubstrate Water Temperature (°C)
Beaver 1	31	5	30	10% SG, 80% Sa, 10% Si	6.4
Beaver 2	28	4	25	5% SG, 80% Sa, 15% Si	3.0
Beaver 3	25	6	30	20% LG, 30% SG, 50% Sa	4.0
Beaver 4	28	3.5	36.5	10% SG, 80% Sa, 10% Si	4.5
9-Mile Hole (near basket site)	3	113	15	5% SG, 25% Sa, 70% Si	3.2

a Si = silt, Sa = sand, SG = small gravel, LG = large gravel

in one of the holes chopped while attempting to locate the baskets. Surface water temperature was 0.9 °C and intrasubstrate temperature was 3.2 °C. Dissolved oxygen was 0 mg/l, and the water had a sulphurous smell. There was no visible flow. Substrate recorded at this site (Table 1) may not accurately represent the precise location where the baskets had been buried. At the time of placement, substrate was recorded as primarily gravel, and the surrounding area was covered in silt and sand.

At the beaver dam 3 m upstream, a constricted flow (<60 cm wide) was found breaching the dam under 15 cm of ice cover. The dissolved oxygen content in this water was 11.5 mg/l. This flow must have continued in a confined area since no velocity or oxygen was detectable in the hole chopped only 3 m downstream.

Contents of egg baskets removed from Beaver Creek in March of 1990 are recorded in Table 2. Several eggs from each basket were missing and may have been crushed and lost through the mesh during basket removal. All eggs had died and ranged in appearance from clear yellow to opaque yellow, grey and black. Those eggs which were not opaque showed very little development.

The baskets in 9-Mile Hole Creek were not retrieved because of the extreme ice conditions. We do not know whether the eggs in those baskets survived and developed, however, conditions measured near the site in March were much less suitable than those at Beaver Creek, where eggs did not survive.

The egg basket which had been shipped to Winnipeg in September of 1989 contained a sample of eggs which was 83% fertilized. It must therefore be concluded that the eggs buried at Beaver Creek

Table 2. Numbers of dead and missing eggs in baskets from Beaver Creek, 1990.

Basket	Dead Eggs	Missing Eggs	Total
Beaver 1	373	27	400
Beaver 2	389	2	400
Beaver 3	389	2	400
Beaver 4	350	50	400

were viable and perished due to unsuitable habitat conditions. Groundwater was evident at both sites when investigated in July (see chapter on groundwater investigations), but may have been insufficient to provide adequate oxygen and remove wastes for successful incubation.

This study once more illustrates how specific and limited suitable incubation habitat is in the lower Nelson River system. The site used on 9-Mile Hole Creek was, in fact, the only area of groundwater upwelling located in that stream during an intensive survey in 1989. Only two groundwater sites were located in Beaver Creek during the same survey, and of those two sites the one used in this study appeared most suitable.

CONCLUSIONS

1. This study once more indicates how specific and limited suitable spawning habitat for brook trout is in the Nelson River system. Ample groundwater upwelling is necessary to provide adequate flow through the fine substrate which is characteristic of this area.

2. The presence of groundwater upwelling in a streambed does not ensure that suitable incubation conditions exist. The degree of upwelling appears to be critical.

RECOMMENDATIONS

1. Detailed groundwater quality studies at known trout spawning areas should be undertaken to better define the habitat conditions necessary for successful egg incubation in the Nelson River system. Parameters measured through the incubation period should include the rate of intrasubstrate flow, oxygen concentration in groundwater, and pH of groundwater.

2. Similar monitoring should be conducted at potential incubation sites in streams where spawning does not occur. The data may then be compared to those measured at known spawning sites, to determine the potential for trout population enhancement through egg transfer and incubation.

PART IV

BROOK TROUT TRANSFER TO KETTLE RIVER

PART IV

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INTRODUCTION

Brook trout stocks within the Kettle River have been isolated from the remainder of the Nelson River system by construction of the Long Spruce Generating Station. It is impossible to assess the impacts of this segregation since additional impacts such as overfishing and habitat degradation have occurred concurrently. At present, brook trout stocks within the Kettle River system are severely depleted. Only four adult brook trout were found in the Kettle River during fisheries investigations in 1985 (Swanson 1986).

To determine the suitability of habitat currently in the Kettle River system, 20 adult brook trout were transferred from the Limestone and Weir rivers in fall of 1987, and tagged with radio transmitters (Swanson et al. 1988). Several of these trout migrated downstream and out of the Long Spruce Reservoir shortly after release. This behaviour was probably due to disorientation related to spawning condition at the time of transfer (Swanson et al 1990). To avoid this complication in 1988, 25 adult brook trout were transferred to the Kettle River in late June from French Creek and Gods River. Nine of these trout were tagged with radio transmitters, the remainder were tagged with numbered spaghetti tags. Monitoring of the 1988 radio-tagged trout showed that trout transferred in the spring/summer are less likely to leave the Kettle River system than if transferred when in spawning condition in fall. During summer of 1988, the trout were located in rearing habitat within the rapids of the Kettle River (Swanson et al 1990).

In fall, they did not migrate out of the system as in 1987, and one was located near an historical spawning pool in the Kettle River. In winter, several tagged trout continued to use the river system or the Long Spruce Reservoir at the tailrace of the Kettle Generating Station.

Results of the 1988 transfer indicated that habitat within the Kettle River system was suitable for summer and winter rearing of brook trout. There is also some indication that historical spawning areas were attractive to brook trout in 1988.

The adult brook trout transfer program was continued in 1989 to supplement the depleted stocks, and to encourage re-establishment of self-sustaining populations. Three of these trout were also tagged with radio transmitters to provide additional information on use of habitat within the Kettle River system.

METHODS

Brook trout were captured by angling in French Creek between May 29 and June 1, 1989. The trout were held in hoop nets in French Creek until air transport was available. On June 3, the trout were transported in tubs by boat to float plane access. While waiting for air transport, water within the tubs was aerated by hand (pouring water from pails). In preparation for transport fifteen trout were transferred to each of two 115-litre mechanically aerated coolers and loaded on a Cessna 185 float plane. The coolers were flown to Gillam and transferred intact to a Bell 206 helicopter. They were immediately transferred to previously prepared holding pens in 9-Mile Hole Creek near the confluence with the Kettle River. The duration of the transfer was approximately one and one half hours.

On the evening of June 5 the trout were weighed and measured, sex was determined by external examination, and a scale sample was removed for ageing purposes. Three of the trout were externally fitted with 15-g, 200-day radio transmitters, according to the technique described in Swanson (1986). Twenty-five trout were tagged with individually numbered floy tags. All twenty-eight trout were held overnight and then released in good condition near the confluence of 9-Mile Hole Creek and the Kettle River on June 6.

Tracking flights to determine the locations of the radio-tagged trout were conducted approximately every three weeks using a Bell 206 helicopter. Equipment and techniques were as described in Swanson (1986).

RESULTS

Twenty-eight brook trout were successfully transferred from French Creek to the Kettle River system in early June of 1989. Three of the trout were tagged with radio transmitters, while the remaining 25 were tagged with Floy spaghetti tags. The tag number, length, weight, age and sex of each transferred trout are presented in Table 1. Radio-tagged trout are represented by frequencies rather than tag number. The three radio-tagged trout were all five years old; two were males and one was a female. All three radio-tags transmitted properly throughout summer and fall. Locations and dates recorded for each radio-tagged trout are presented in Figures 1-3. Each of the trout had moved downstream into the Long Spruce Reservoir before the first tracking flight was conducted on June 23.

The trout tagged with transmitter number 49.170 remained in the upstream portion of the reservoir during summer and exhibited localized movements only (Figure 1). In late fall this fish moved upstream to a narrow deep area which tends to remain open during winter. It was still located at this site when last detected on November 26.

The other two radio-tagged trout were first located within the reservoir downstream of the Kettle River, and exhibited similar patterns of movement throughout the summer. The trout tagged with transmitter number 49.920 remained along the north shore of the reservoir during summer (Figure 2). By late August it had moved upstream and into a deep portion of the reservoir. In September

Table 1. Tag numbers and physical characteristics of brook trout transferred to the Kettle River system, June 6, 1989.

Tag Number	Fork Length (mm)	Weight (g)	Age	Sex
49.170[a]	462	1025	5	M
49.920[a]	468	1000	5	F
49.429[a]	470	950	5	M
OR00703	401	500	4	F
OR00862	469	1050	5	M
OR00863	504	1300	6	F
OR00864	463	1025	5	M
OR00865	512	1200	6	M
OR00866	513	1325	6	M
OR00867	373	600	4	F
OR00868	355	550	3	F
OR00869	477	1100	5	M
OR00870	463	900	5	M
OR00871	484	1225	5	M
OR00872	487	1200	5	M
OR00873	450	900	5	M
OR00980	446	850	5	M
OR00981	458	850	5	M
OR00982	375	600	4	F
OR00983	482	1025	5	M
OR00984-85	407	675	4	F
OR00986	464	950	5	F
OR00987	520	1275	6	M
OR00988	531	1350	6	M
OR00989	425	700	5	M
OR00990	486	1150	6	M
OR00999	458	900	5	M
OR00704	470	800	5	M

a - Radio tag frequency (Mhz).

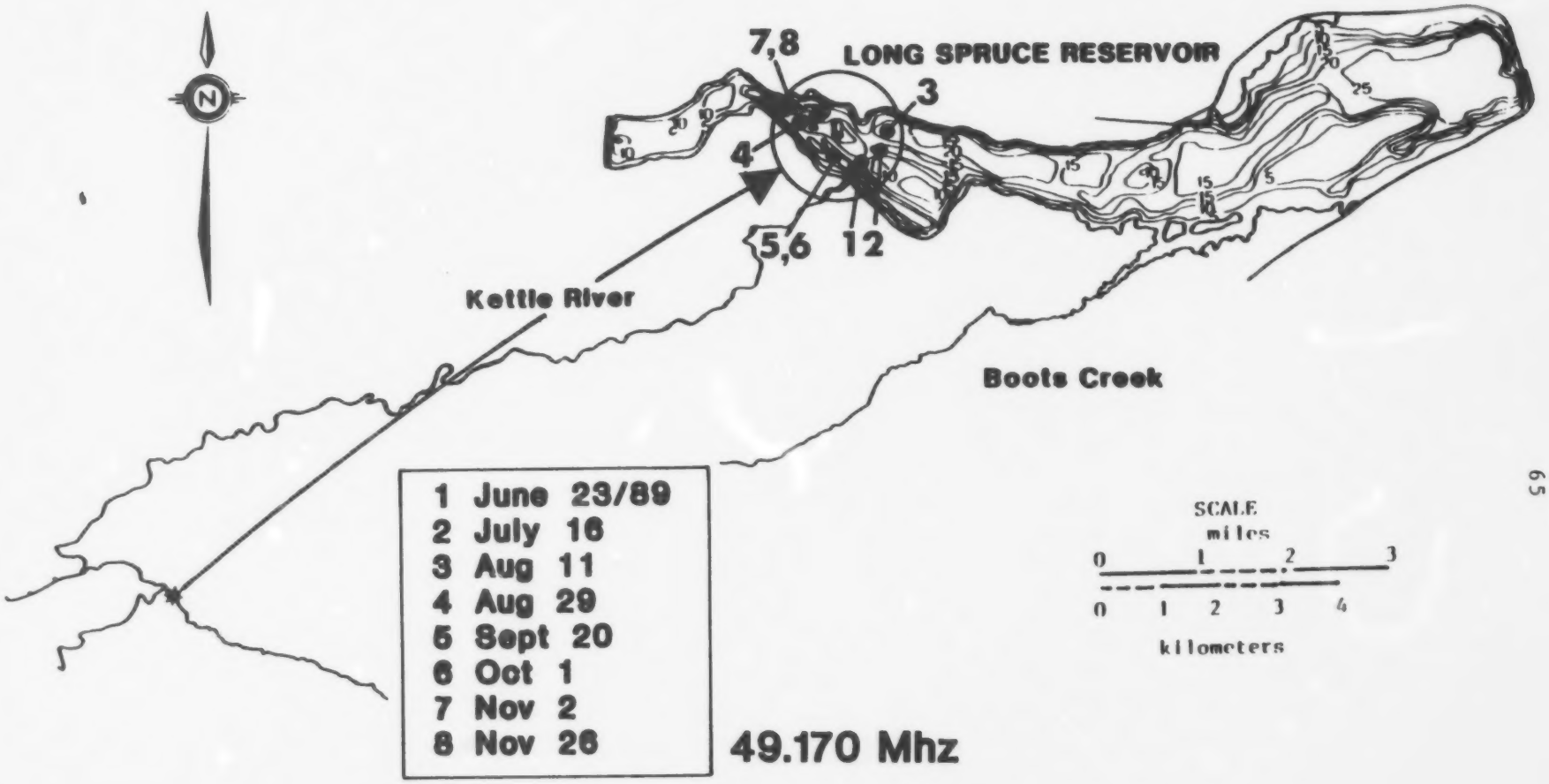

Figure 1. Locations of radio-tagged brook trout 49.170 Mhz in 1989.

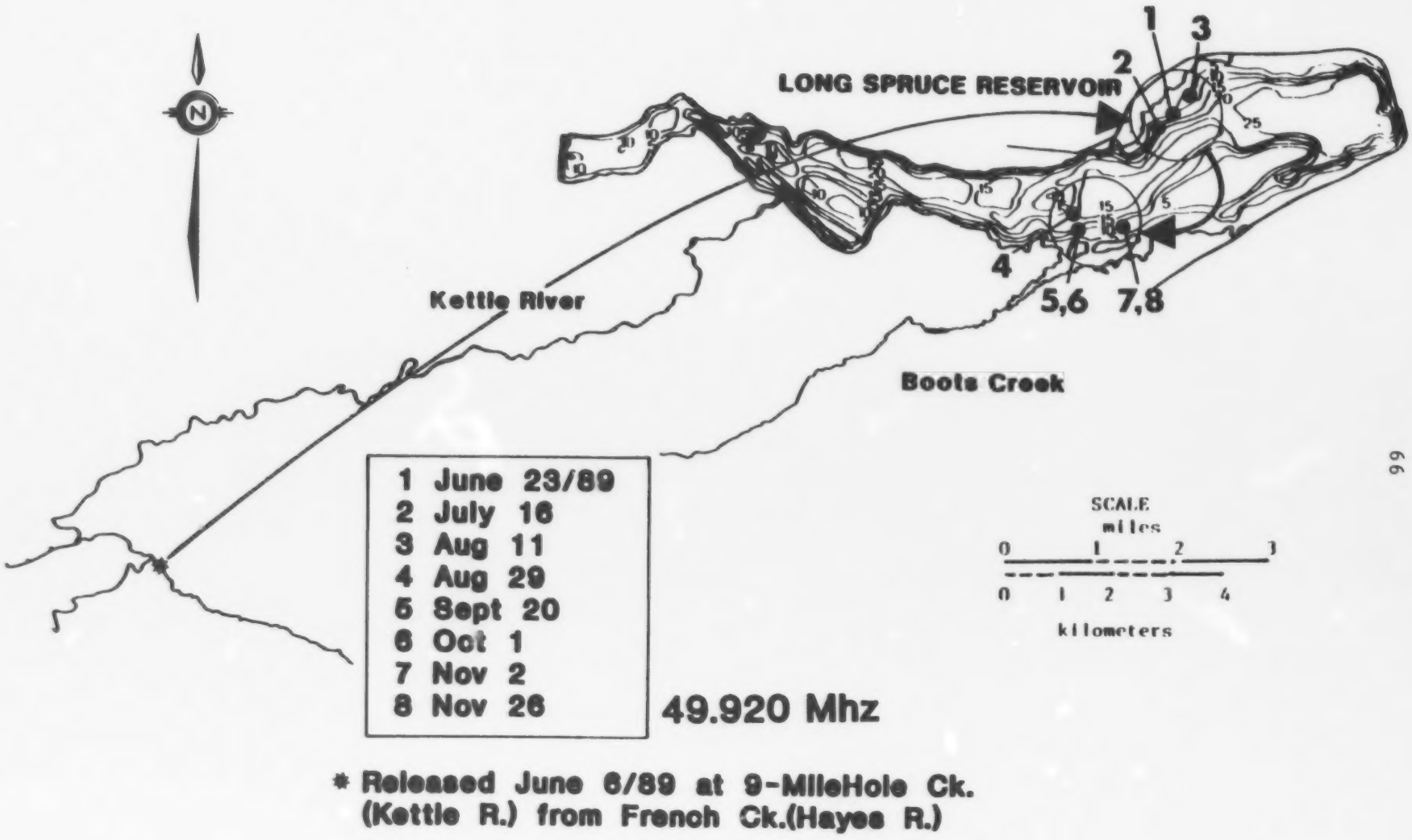

Figure 2. Locations of radio-tagged brook trout 49.920 Mhz in 1989.

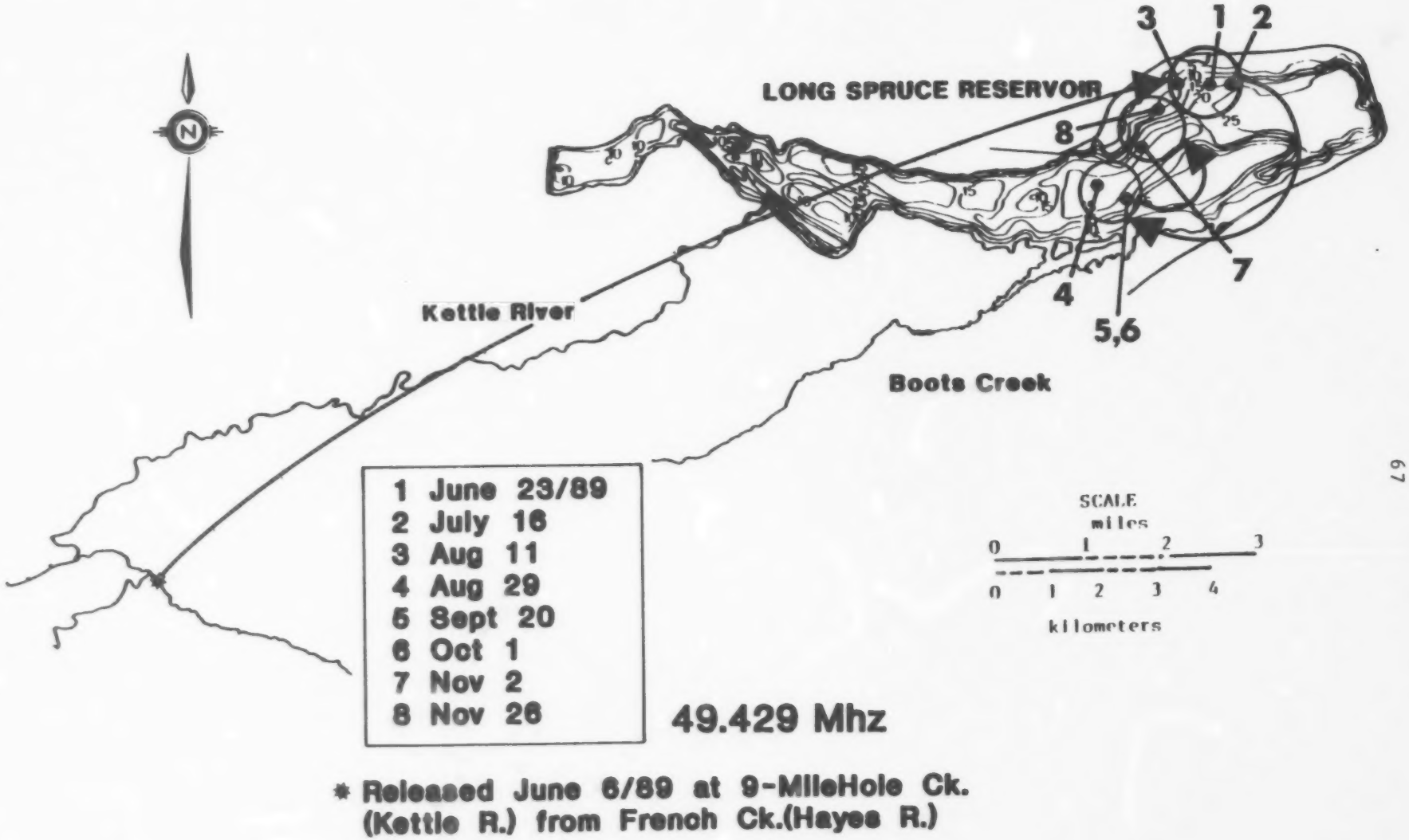

Figure 3. Locations of radio-tagged brook trout 49.429 Mhz in 1989.

and October it moved into shallower water along the south shore near the mouth of Boots Creek. The final recorded locations, in November, were in the same area. The trout tagged with transmitter number 49.429 also remained along the north shore of the reservoir during summer, moved to deeper water upstream by late August, and then inshore to shallower water in early fall (Figure 3). It did not remain in this area in November, as did number 49.920, but moved across the reservoir to the north shore.

To date, no information on any of the 25 trout released with numbered spaghetti tags has been received.

DISCUSSION

The transfer technique and equipment used in 1989 proved much less stressful on the fish than those used in 1988. Only 1 of 29 fish died between transport in the float plane and release at 9-Mile Hole Creek. This death is thought to be due to poor condition of the fish before transport. The use of aerated coolers which were transferred intact, without disturbance of the fish, between the float plane and the helicopter was key to the success of this process. Transfer in spring/summer with sufficient aeration allows introduction of trout which will remain in the system and may potentially enhance the depleted stocks.

It is curious that all three of the trout which were radio-tagged in 1989 moved downstream to the Long Spruce Reservoir shortly after release, while most of those released in 1988 had remained in the streams (Swanson et al. 1990). It is impossible to determine how many of the trout tagged with numbered spaghetti tags remained in the streams, and how many moved out to the reservoir. Unfortunately the sample size of radio-tagged trout is too small to allow comparisons of behaviour between 1988 and 1989.

Movements of each of the three radio-tagged trout within the reservoir indicate that they were in good condition and reacted predictably to seasonal changes (e.g. movements of radio tags 49.429 and 49.920 to deeper water during the warmest season; movement of radio tag 49.170 in November to an area which generally remains ice free during winter). Some of the areas used by these trout, such as the mouths of Boots Creek and the Kettle river, were

also used by trout transferred in 1987 (Swanson et al. 1988).

The success of this transfer in supplementing the brook trout stocks within the Kettle River system is not yet known. Some information may be forthcoming through tag returns, but is unlikely due to the small number of tagged fish. One means of determining whether any of these trout, or those released in 1988, have remained and adapted to the Kettle River system would be to monitor historical spawning sites in fall in an attempt to observe or capture tagged fish.

CONCLUSIONS

1. The portable fish transfer units used in 1989 were both easily handled and suitable for maintaining fish in good condition. Aerated coolers allow a continuous supply of oxygen and lowered stress since they may be transferred intact from one aircraft to another.

2. All three of the radio-tagged trout moved downstream to the Long Spruce Reservoir, however they did not continue downstream past the generating station. These fish exhibited movements which indicated that they remained in good condition.

3. The locations of trout tagged with spaghetti tags are as yet unknown. They may be in riverine habitat of the Kettle River system, in the Long Spruce Reservior, or some may have moved downstream past the Long Spruce Generating Station.

RECOMMENDATIONS

1. Annual transfers of adult brook trout should continue. These trout will supplement the depleted stocks in the Kettle River and increase the potential for re-establishment of self-sustaining populations within the system.

2. The historical spawning areas within the Kettle River should be occasionally checked, or intensively monitored, during the spawning season to determine whether any trout are using these areas. Observations of tagged trout would indicate the participation of transferred trout.

PART V

BROOK TROUT TELEMETRY

PART V

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INTRODUCTION

In order to fully understand the impacts of hydroelectric development on brook trout in the Nelson River system, movements and habitat-use patterns of this species must be determined for all seasons. The extent of brook trout migration to various habitats in the river system and the estuary will partially determine how severely impoundments will affect populations. The degree of anadromy in brook trout populations has recently been assessed as much lower than previous estimates. Gaboury (1980) estimated that 25% of Nelson River trout utilized the estuary during part of their life, while recent estimates have been from 8% (Swanson 1986) to less than 1% (Swanson et al. 1988; Swanson et al. 1990). In part, these variations may result from differences in sample location. Swanson and Kansas (1987) found that those trout which inhabit streams closer to Hudson Bay are more likely to utilize the estuary than those further upstream in the system, i.e. the brook trout in the Nelson River system appear to be opportunistically anadromous. Historically, anadromy may have been much more common in Limestone River brook trout, perhaps as high as 24%, and may now be artificially lowered by the effects of angler harvest (Swanson et al. 1988).

Radio-telemetry and fish fence studies in recent years have provided information on brook trout movements and habitat use during various seasons. Fall spawning migrations and locations in tributaries to the Nelson and Limestone rivers, and in the Limestone River proper, have been well documented (Gaboury 1980;

Swanson and Kansas 1987; Swanson et al. 1988; Swanson et al. 1990). Radio-telemetry conducted in 1985 and 1986 revealed patterns of winter habitat use by brook trout tagged in the Limestone and Nelson rivers in fall. Most trout tagged in the Limestone River overwintered there. Some, especially those tagged in the Nelson River, undertook significant downstream migrations in late fall and winter (Swanson 1986; Swanson et al. 1987). Under similar conditions in other rivers, brook trout have used estuarine habitat in winter (Smith and Saunders 1958; Castonguay et al. 1982); in the Nelson River system only 1 of 12 radio-tagged brook trout migrated down to the estuary during winter (Swanson 1986).

Little information on habitat use by adult brook trout in spring and summer has been collected to date. Five Nelson River brook trout were radio-tagged in late May and early June of 1986 and monitored until fall. Results indicated that brook trout use the Nelson River as summer habitat, and migrate opportunistically within the system (Swanson et al. 1987). In order to gather more information, the 1989 radio-telemetry study was undertaken in the Limestone and Nelson rivers.

METHODS

Throughout the summer of 1989 angling was conducted on the Limestone River and at the mouth of Leslie Creek to capture adult brook trout for radio-tagging. Brook trout of suitable size (> 300-mm fork length) were weighed and measured, sex was determined from external characteristics, and a scale sample was removed for ageing purposes. A 15-g, 200-day radio transmitter was attached externally as described in Swanson (1986). Trout were released immediately following tagging. One brook trout was also captured during gill netting below the spillway of the Long Spruce Generating Station, and was similarly tagged and released.

During the summer and fall, tracking flights to determine locations of the radio-tagged trout were conducted approximately every three weeks using a Bell 206 helicopter. Equipment and techniques were as described in Swanson (1986). Flights continued on a less frequent basis through the winter of 1989-90. The last transmissions from two of the tags were detected on April 4, 1990.

RESULTS

Eleven adult brook trout were tagged with radio transmitters during this study: eight in the Limestone River and three in the Nelson River. Physical characteristics of each tagged fish, along with dates and locations of tagging, are summarized in Table 1. Ages of tagged fish ranged from three to six years. Five were males and six were females.

A record of locations of each fish, as determined by tracking flights throughout the 1989-90 monitoring period, is presented by tag in Figures 1-11. If a tag was not located on a tracking flight it is indicated by a question mark following the date in the legend. In such instances, either the trout had actually emigrated from the search area, or technical or human problems prevented the transmission signal from being detected. In the Nelson River area, during the flight on October 1, the latter cause is most probable since none of the tags was detected.

Although the tags are designed to last 200 days the actual transmission life varies and is partially dependent upon environmental conditions, especially temperature.

Two of the eleven transmitters provided little data as their fish were removed shortly after tagging. The trout carrying tag 49.110 Mhz, which had been tagged on July 21 immediately downstream of the road crossing of the Limestone River, was captured and removed by an angler at the same site four days later (Figure 1). Tag 49.670 Mhz was found in the bottom of the upstream fish fence in 9-Mile Creek on September 19 (Figure 2). This tag had been

Table 1. Physical characteristics, location and date of tagging of each radio-tagged brook trout in the Limestone-Nelson River system, 1989.

Tag Number	Tagging Location	Date Tagged	Length (mm)	Weight (g)	Age	Sex
49.729	Mouth of CN Ck.	July 29	475	1550	5	M
49.110	Limestone R. Road Crossing	July 21	550	1750	6	M
49.670	Limestone R. - 5-Mile Hole	Aug. 19	320	1050	3	F
49.970	Mouth of CN Ck.	July 30	420	1175	4	M
49.269	Mouth of CN Ck.	July 29	440	1000	4	F
49.890	Mouth of 9-Mile Ck.	July 21	505	1650	6	M
49.767	Mouth of CN Ck.	July 30	395	980	4	F
49.749	Mouth of CN Ck.	July 29	465	1500	5	M
49.850	Mouth of Leslie Ck.	July 26	495	1850	5	F
49.649	Mouth of Leslie Ck.	July 26	430	1100	4	F
49.690	Spillway of Long Spruce G.S.	June 27	410	1000	4	F

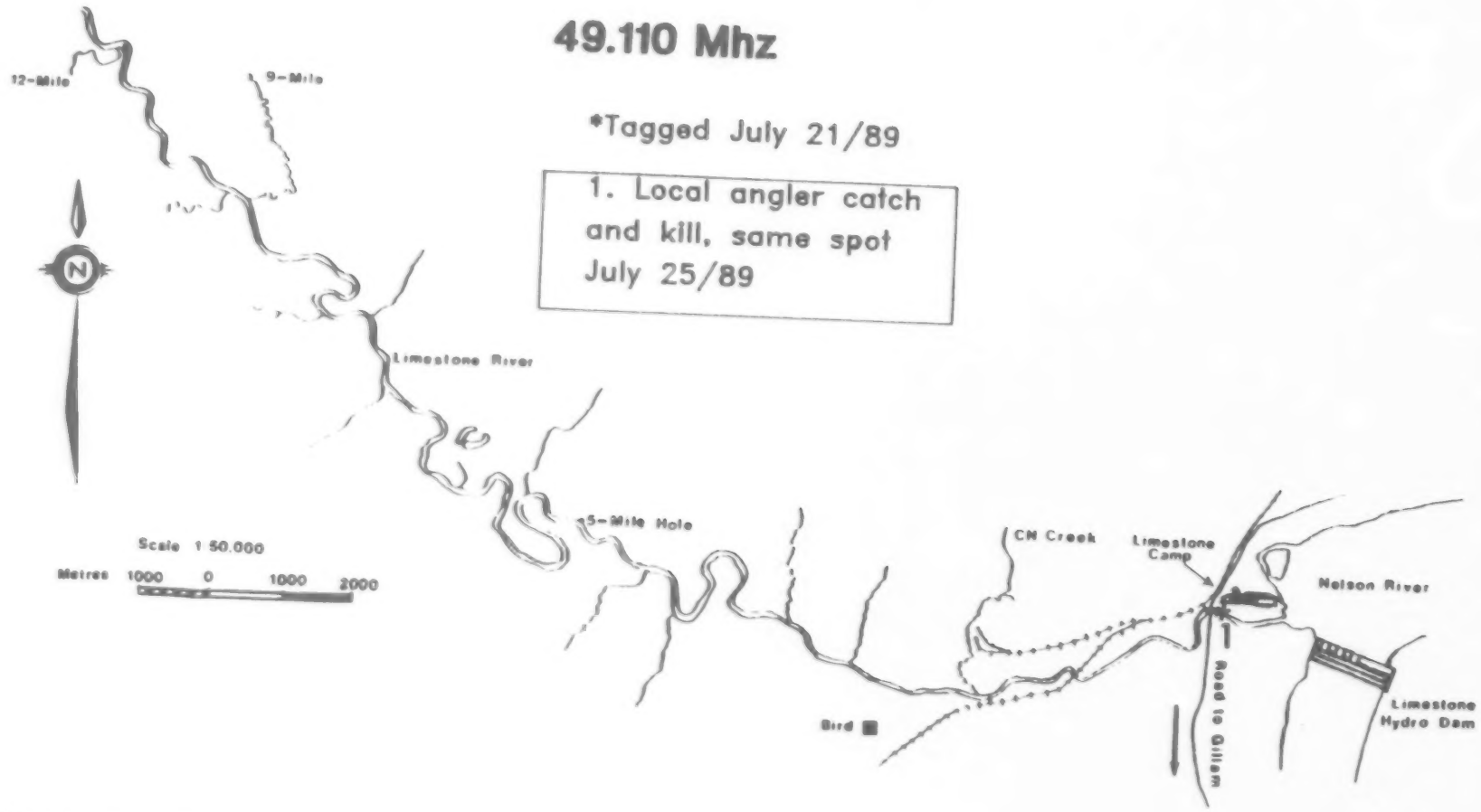

Fig. 1. Location of radio-tagged brook trout 49.110 Mhz in 1989.

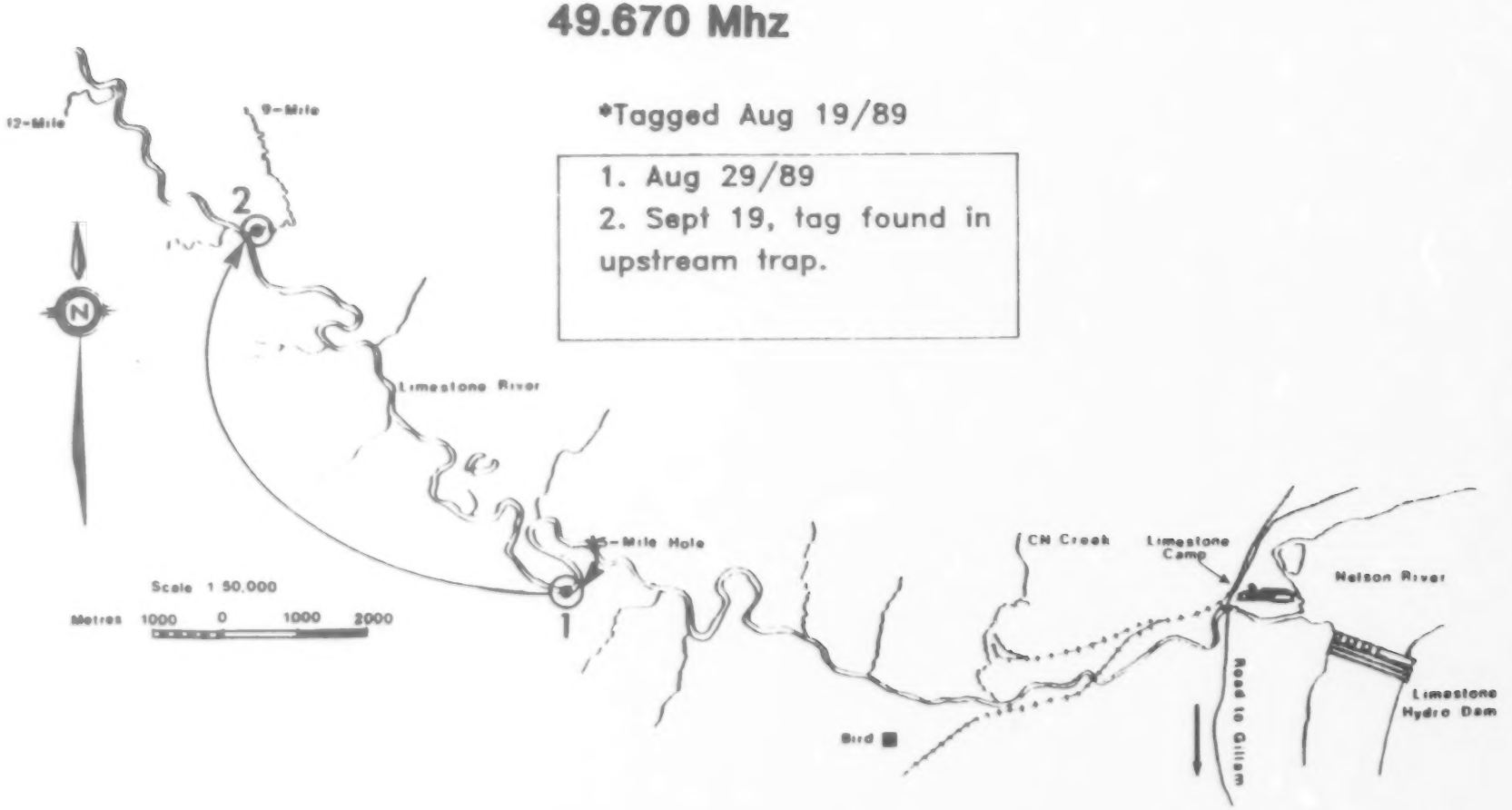

Fig. 2. Locations of radio-tagged brook trout 49.670 Mhz in 1989.

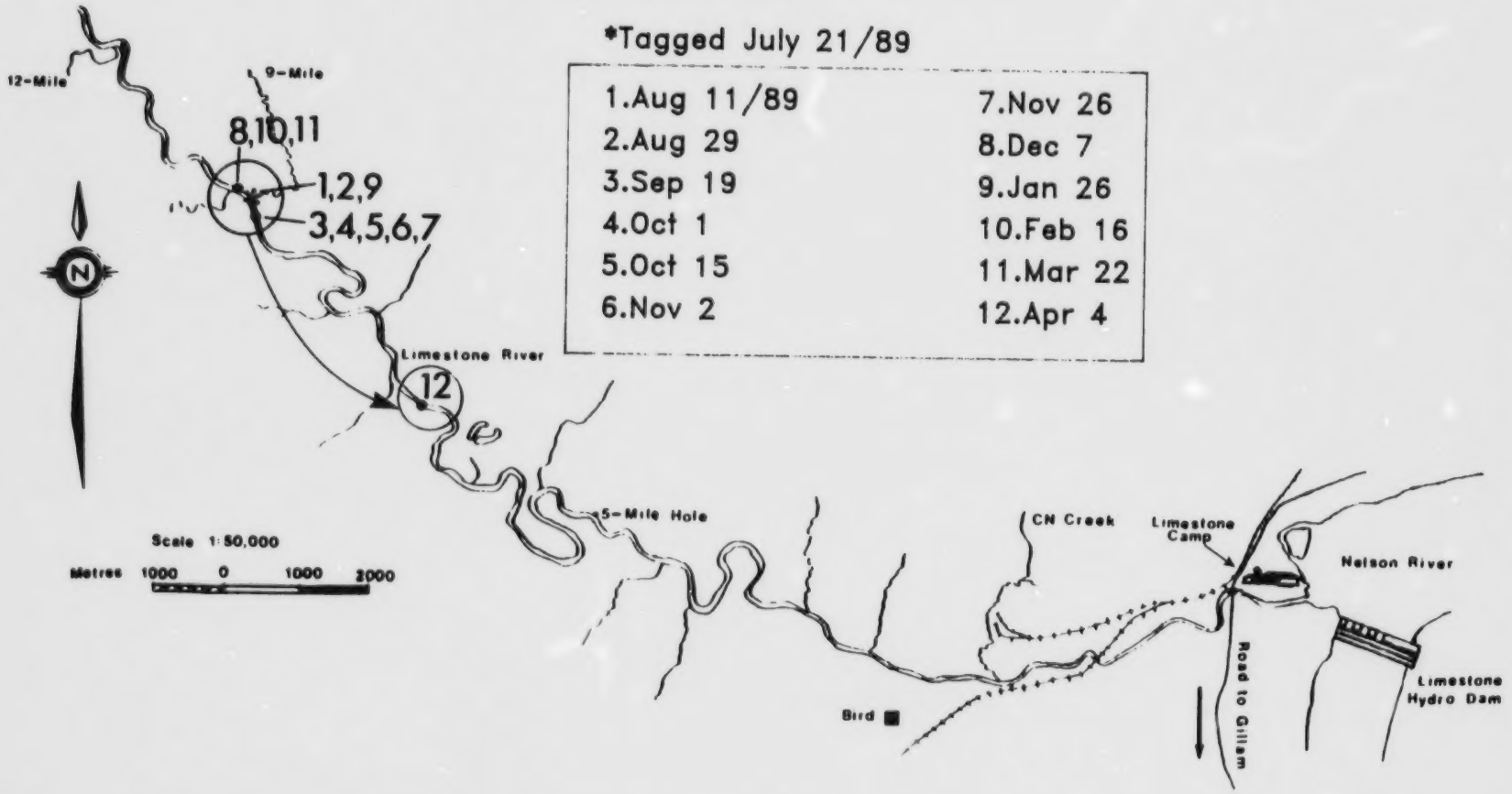

Fig. 3. Locations of radio-tagged brook trout 49.890 Mhz in 1989-90.

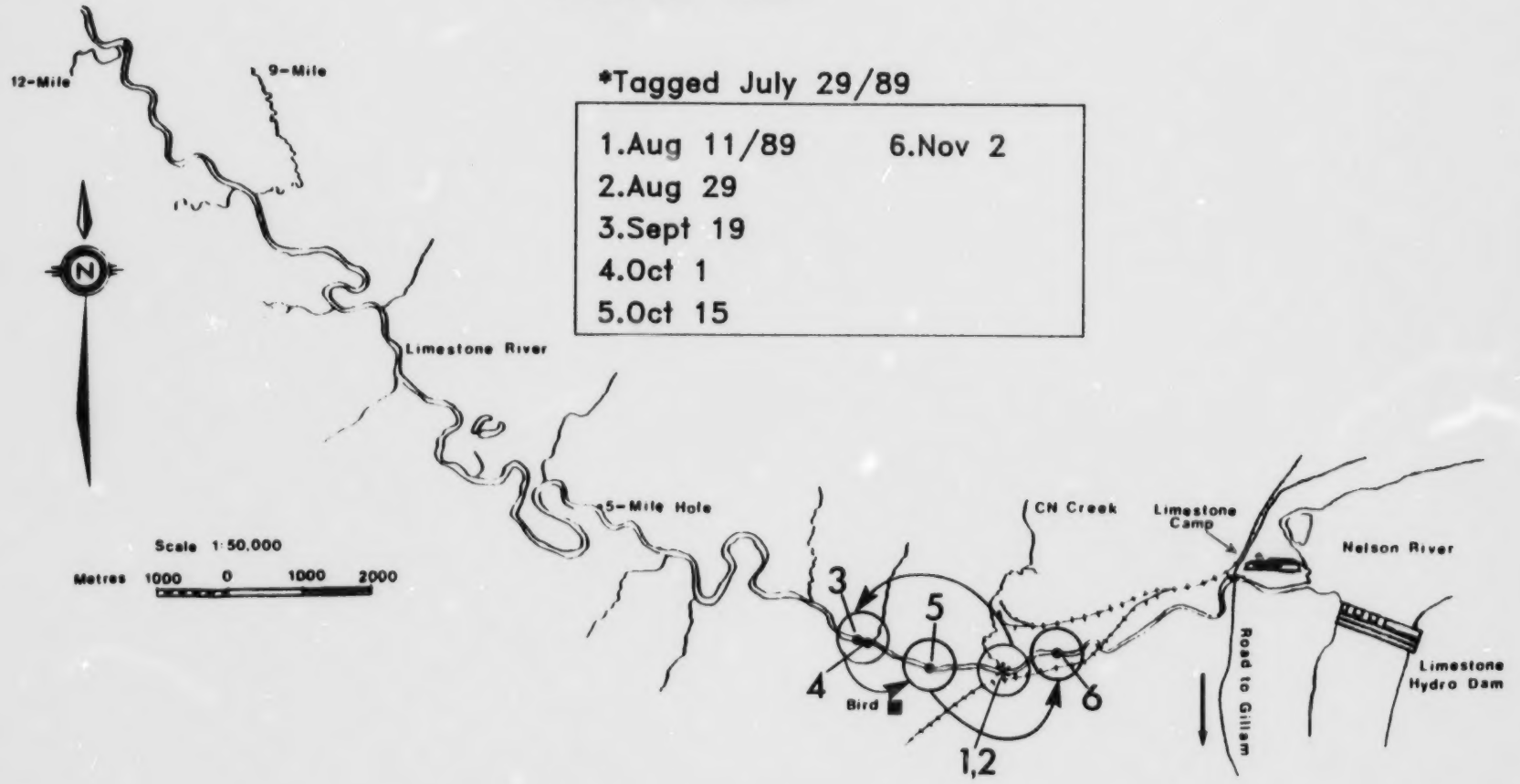

Fig. 4. Locations of radio-tagged brook trout 49.269 Mhz in 1989.

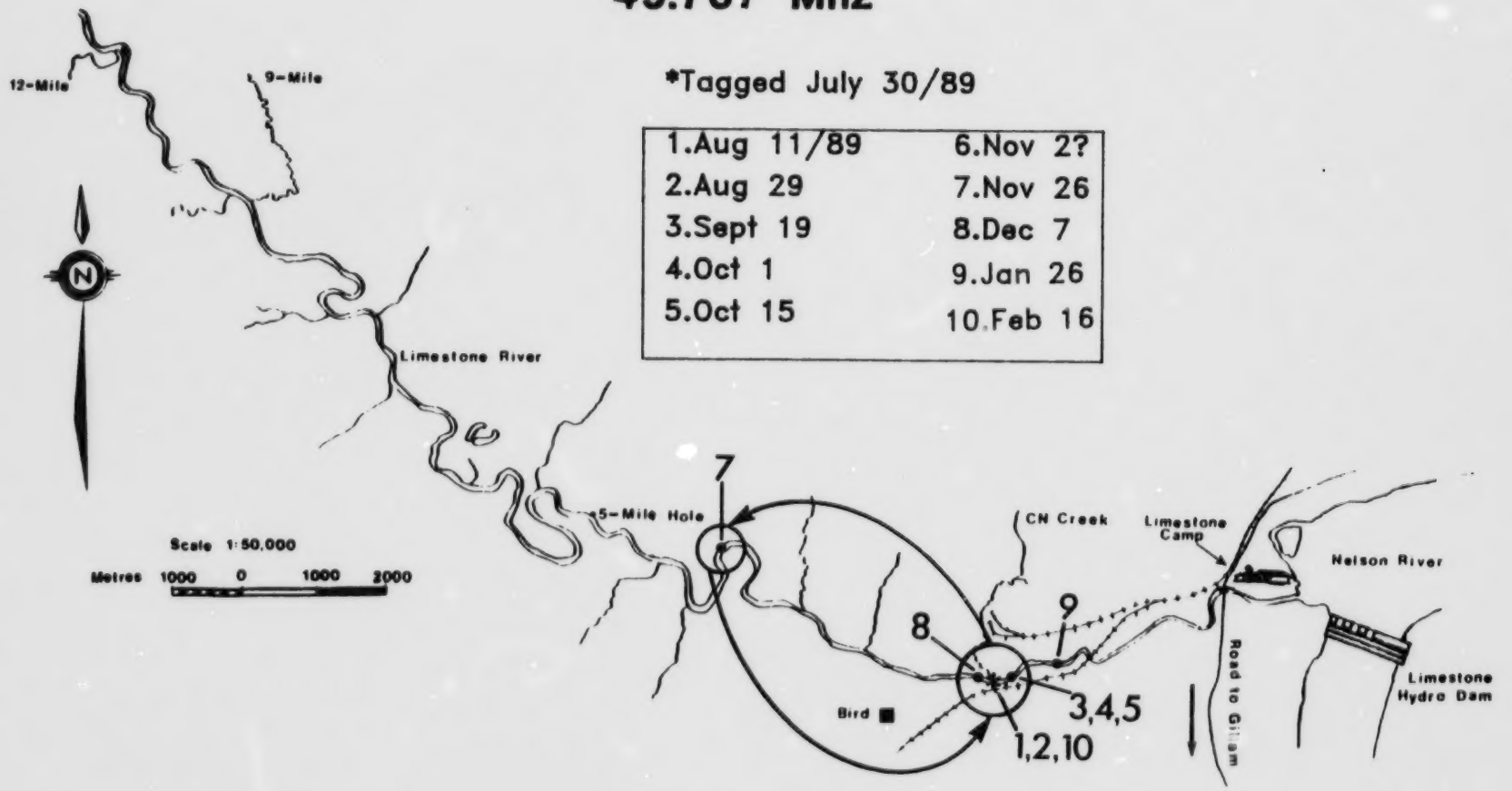

Fig. 5. Locations of radio-tagged brook trout 49.767 Mhz in 1989-90.

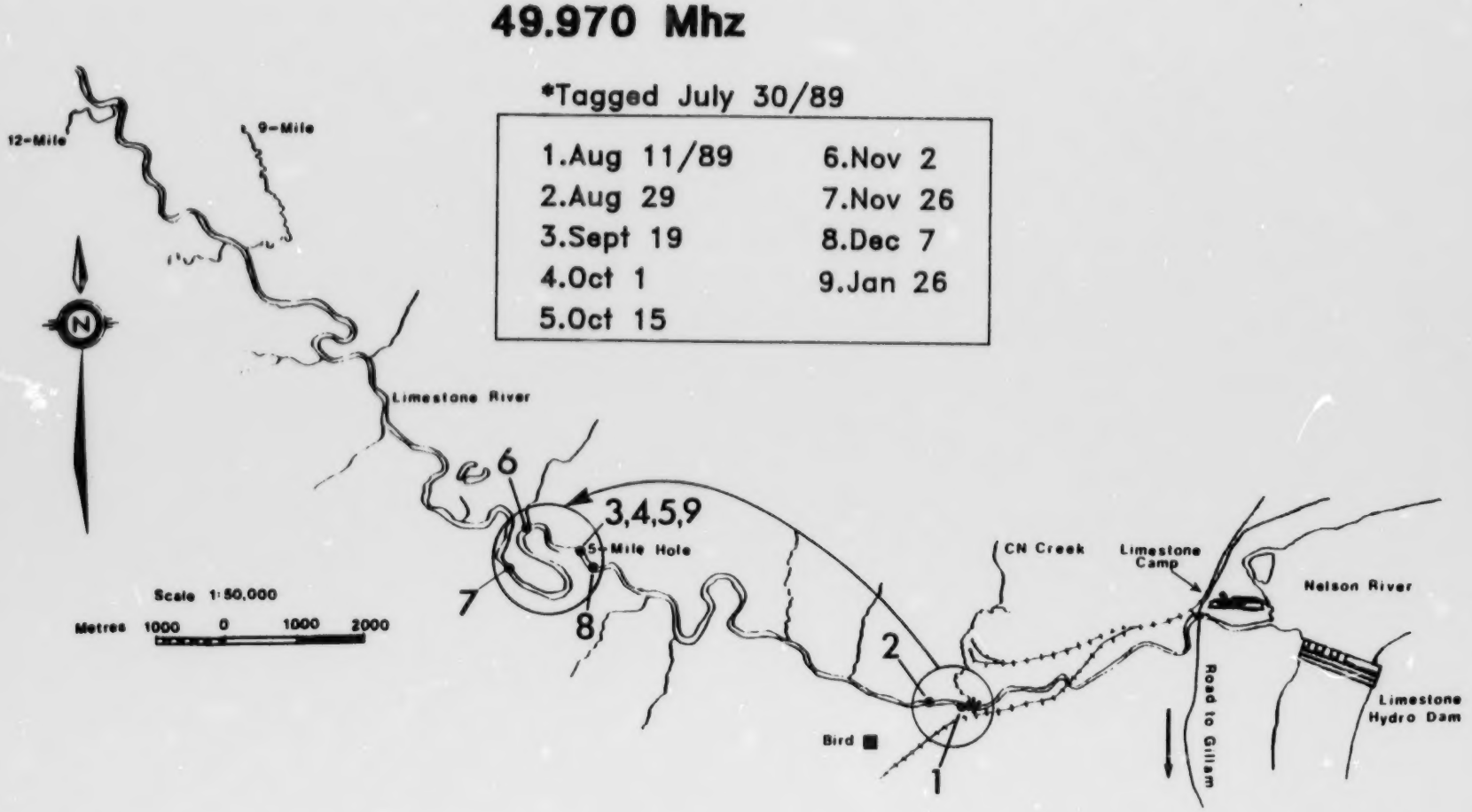

Fig. 6. Locations of radio-tagged brook trout 49.970 Mhz in 1989-90.

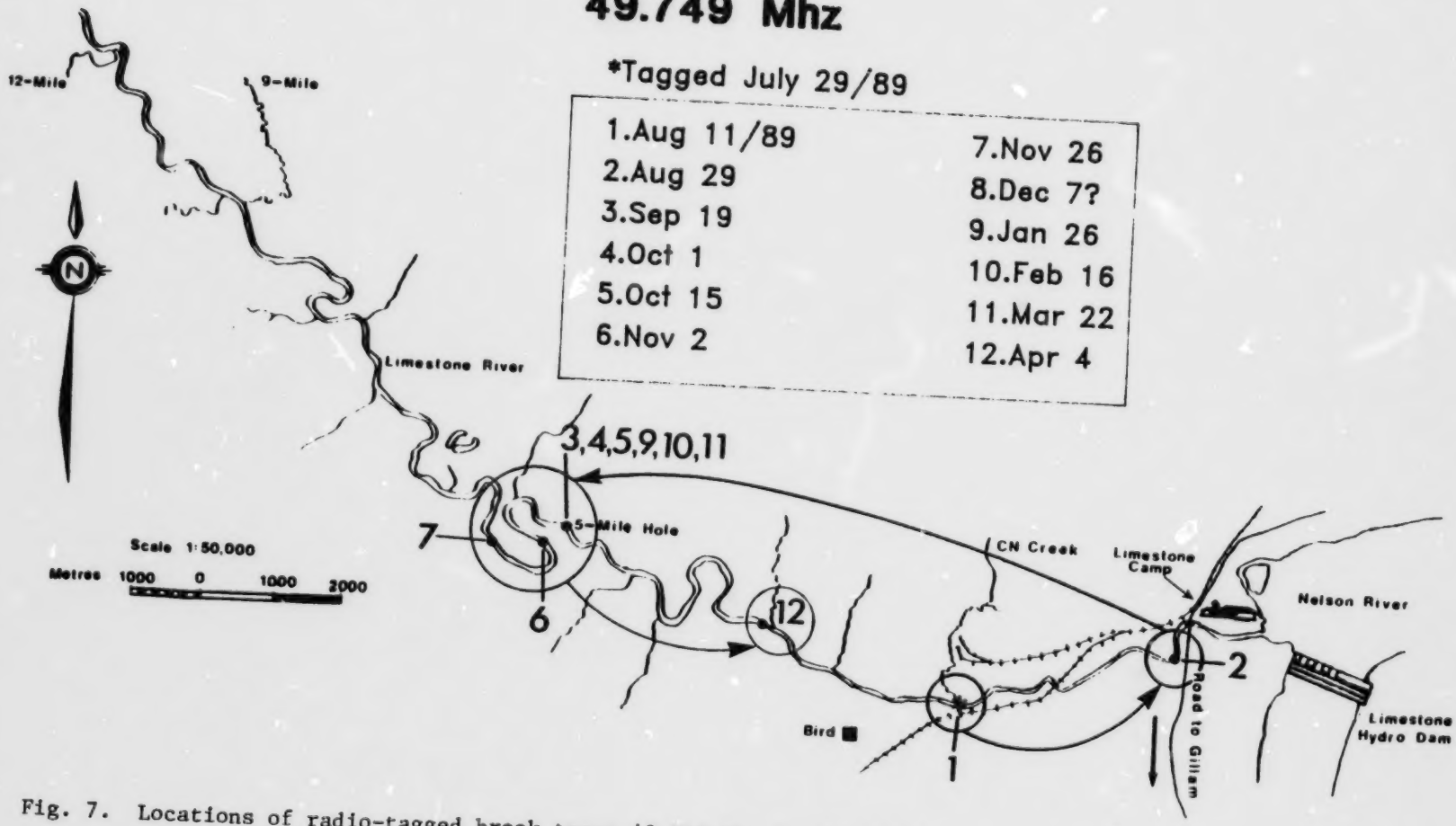

Fig. 7. Locations of radio-tagged brook trout 49.749 Mhz in 1989-90.

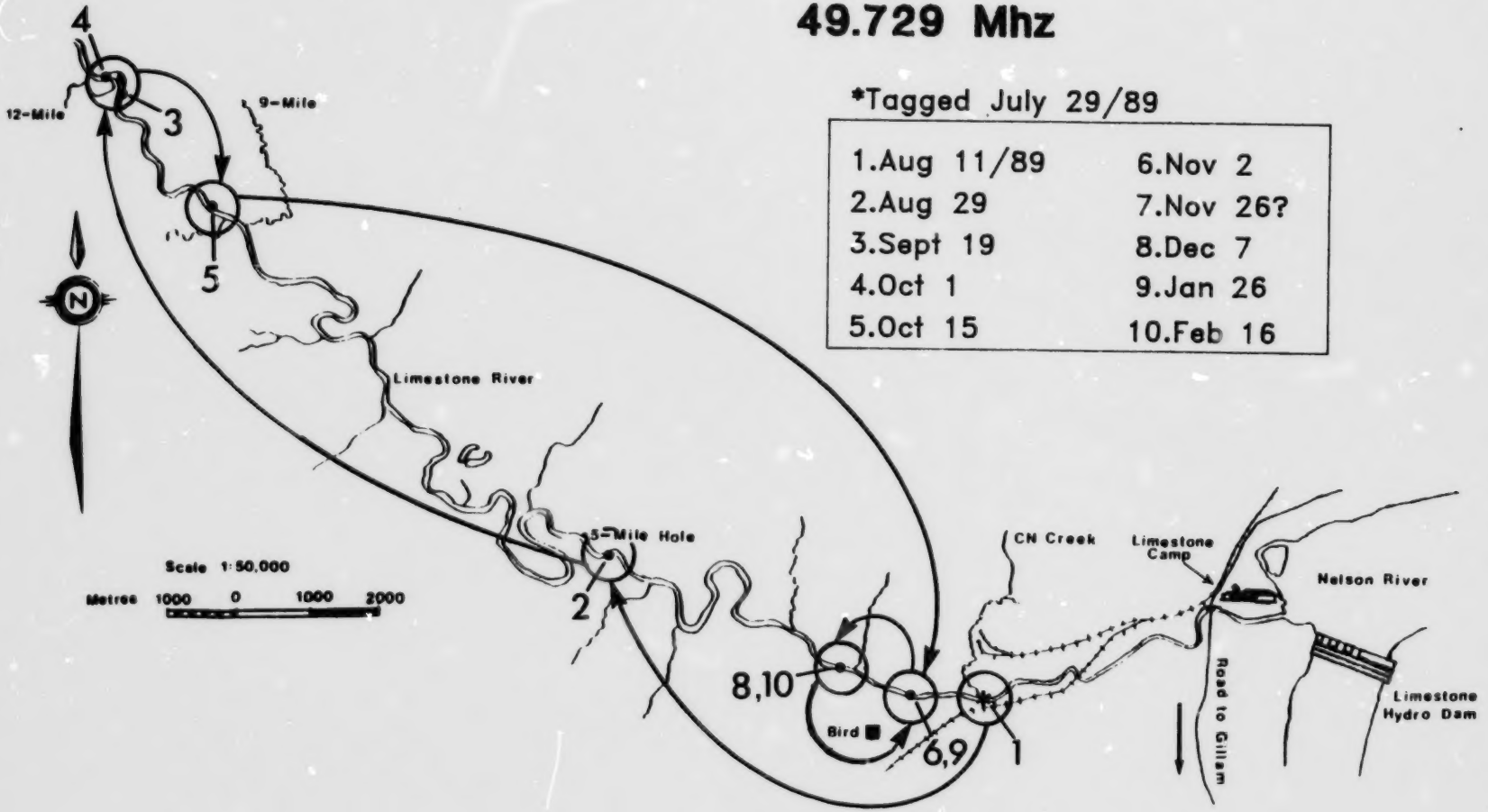

Fig. 8. Locations of radio-tagged brook trout 49.729 Mhz in 1989-90.

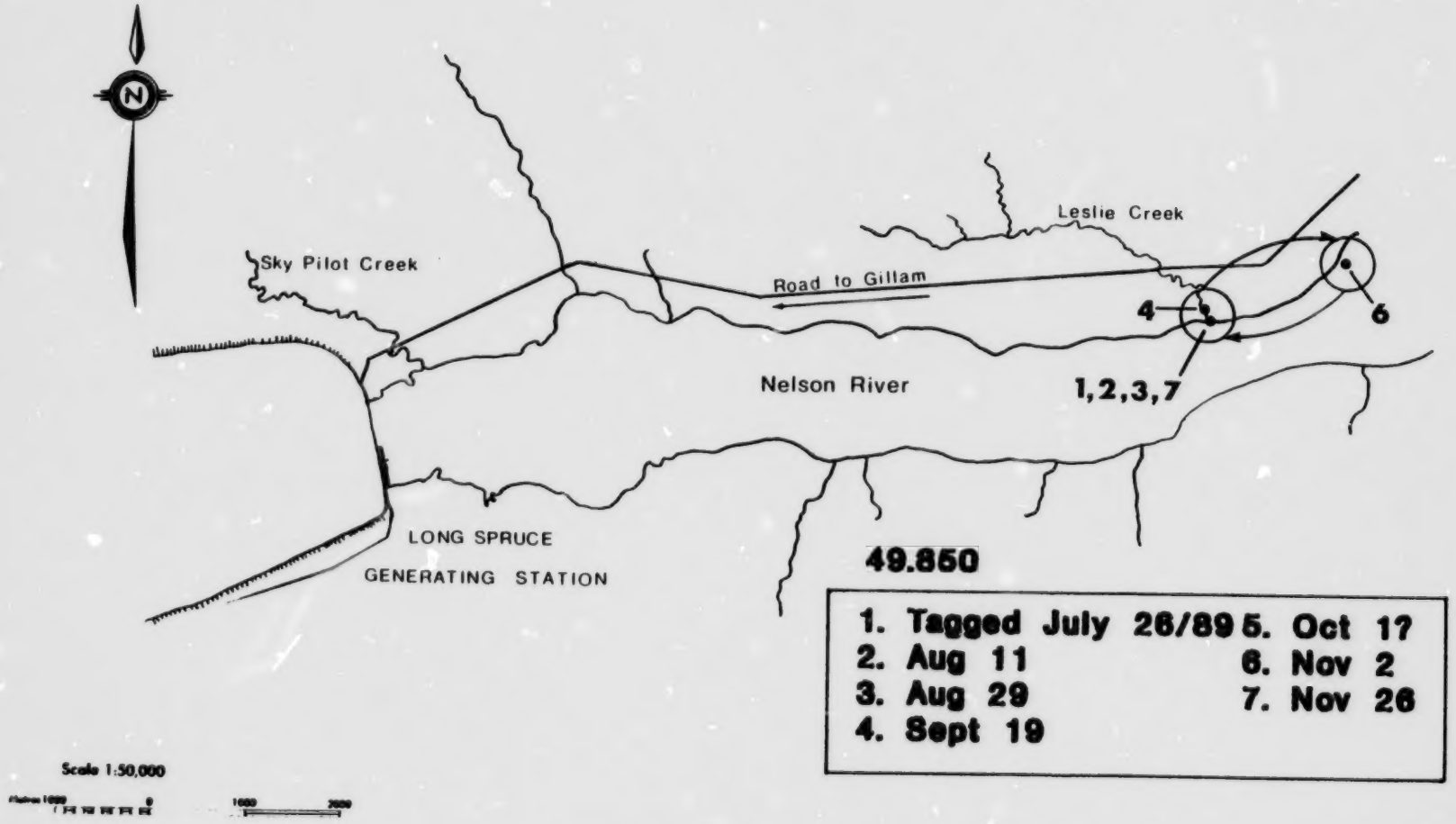

Fig. 9. Locations of radio-tagged brook trout 49.850 Mhz in 1989.

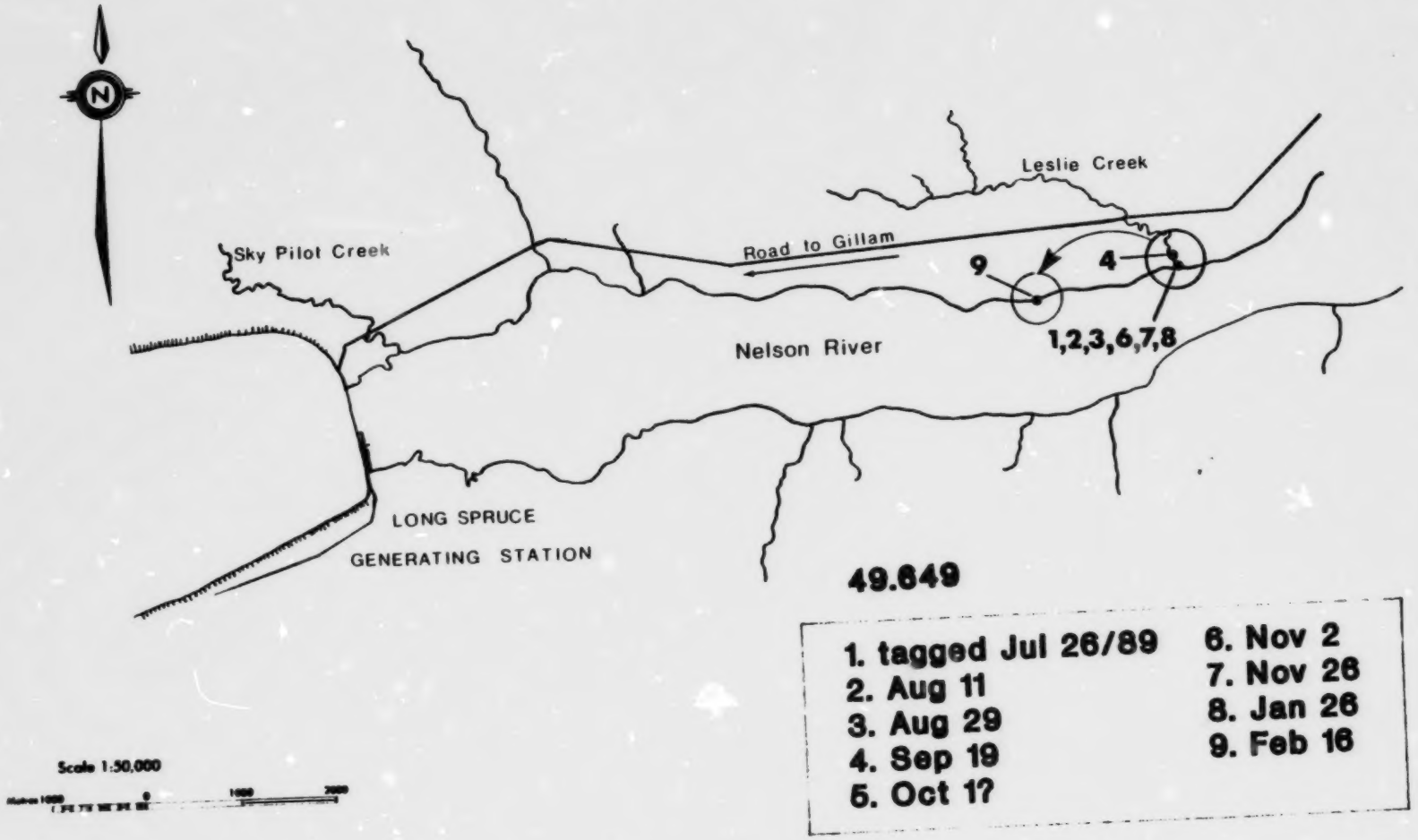

Fig. 10. Locations of radio-tagged brook trout 49.649 Mhz in 1989-90.

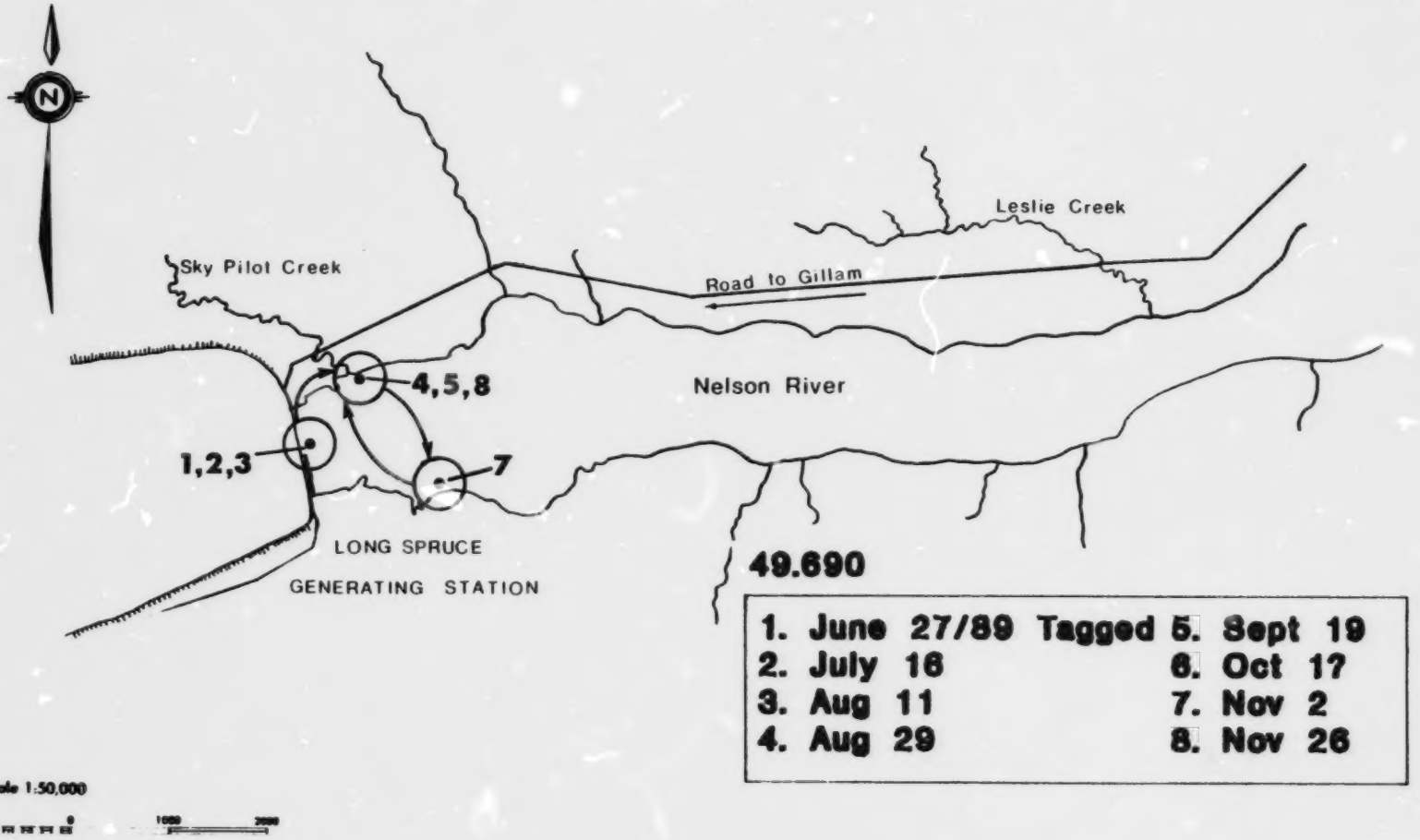

Fig. 11. Locations of radio-tagged brook trout 49.690 Mhz in 1989.

attached to the fish with an improvised apparatus rather than the usual proven device, and had fallen off. The trout had been tagged at 5-Mile Hole in the Limestone River on August 29. It had apparently migrated into 9-Mile Creek to spawn.

Brook trout number 49.890 Mhz was tagged on July 21 at the mouth of 9-Mile Creek (Figure 3). This fish remained in that general area through summer, fall and winter, and was last detected approximately 6 km downstream of 9-Mile Creek on April 4.

Five trout were captured and radio-tagged in the Limestone River at the mouth of CN Creek on July 29 and 30. The trout tagged with transmitter 49.269 Mhz remained within 2 km of CN Creek, moving first upstream in early fall and then slowly downstream (Figure 4). It was not located after November 2. Trout number 49.767 Mhz also remained fairly close to CN Creek, moving signficiantly upstream only once (almost to 5-Mile Hole), in late fall, then returning to the CN Creek area for the winter (Figure 5). Two of the trout tagged at CN Creek, 49.970 Mhz (Figure 6) and 49.749 Mhz (Figure 7), exhibited similar movements upstream to 5-Mile Hole in fall, then slightly further upstream in November and back to 5-Mile Hole. Trout number 49.970 Mhz was at 5-Mile Hole when last located on January 26. Trout number 49.749 Mhz was not located in December but was at 5-Mile Hole on January 26, and remained there until March 22. This transmitter was still operating on April 4 when the fish was located downstream of 5-Mile Hole, approximately half way to CN Creek. One of the five trout tagged at CN Creek, 49.729 Mhz, migrated upstream to 12-Mile Creek by fall and then slowly back downstream to near CN Creek by

December (Figure 8). It was last located on Febuary 16 2 km upstream of CN Creek.

The two brook trout captured and radio tagged at the mouth of Leslie Creek in the Nelson River remained in that vicinity through the summer and fall (Figures 9 and 10). The trout tagged with transmitter 49.850 Mhz was not located after November 26 (Figure 9). Trout number 49.649 Mhz remained near Leslie Creek during winter and was last detected on Febuary 16 (Figure 10). The trout tagged below the Long Spruce Generating Station (49.690) on June 27 remained in that general area, moving closer to Sky Pilot Creek in early fall (Figure 11). It was last detected on November 26.

DISCUSSION

Movements of the trout radio-tagged in the Limestone and Nelson rivers during spring and summer of 1989 clearly indicate that adult brook trout are fairly sedentary during summer and do not undertake notable migrations until fall. In fall, adult brook trout migrate to spawning areas either in the Limestone River proper or in tributaries to the Limestone and Nelson rivers (Swanson 1986; Swanson and Kansas 1987; Swanson et al. 1988). Movements of radio-tagged trout in the Limestone River in fall of 1989 indicate that they likely spawned at 5-Mile Hole, CN Creek, 9-Mile Creek and 12-Mile Creek. The radio-tagged trout in the Nelson River likely spawned in Sky Pilot and Leslie creeks.

Previous tagging studies have shown that most brook trout remain in the Limestone River during winter, while a few move downstream into the Nelson River or even the estuary (Swanson 1986; Swanson and Kansas 1987). The results of this study support those conclusions. Five of six radio-tagged trout in the Limestone River in fall of 1989 remained there through the winter. One was not detected after November 2. This fish may have migrated downstream into the Nelson River, upstream out of the tracking range, or the tag may have ceased to transmit. Two of the radio-tagged trout in the Nelson River were not detected after late November. These fish may also have migrated downstream, or the tags may have ceased to transmit. The other Nelson River trout remained near the mouth of Leslie Creek, exhibiting only localized movements through the winter.

The number of brook trout which migrate downstream in the Nelson River, and especially those which move to the estuary, is smaller than previously thought (Swanson 1986; Swanson and Kansas 1987). Construction of the generating stations which are planned for the Nelson River will certainly preclude migrations of these fish, but more significantly the currently used riverine habitat will be destroyed. Impoundment of the Nelson River as planned will destroy riverine habitat, replacing it with reservoir conditions in isolated forebays. Under these conditions, rearing of large brook trout within the Nelson River, as monitored in this study, will not be possible. Change in habitat from riverine to reservoir conditions alters the invertebrate food base and fish species composition (Hynes 1970; Baxter 1977). Brook trout will no longer maintain the selective advantage they have in shallow fast water (Power 1980; Raleigh 1982).

The availability of Nelson River habitat to Limestone River fish decreases competition within the Limestone River population, and provides resources which allow growth of trophy-size brook trout. It is believed that the loss of this habitat, although currently used by only a small number of Limestone River trout, will result in a population with fewer trophy fish.

CONCLUSIONS

1. Adult brook trout remain within the Limestone and Nelson rivers in summer, and do not move signficantly. In fall they undertake migrations to spawning sites in the Limestone River or tributaries to the Limestone and Nelson rivers. In winter most remain in the Limestone or Nelson rivers; a few undertake signficant downstream migrations, some as far as the estuary.

2. Construction of the planned generating stations on the Nelson River will preclude use of the mainstem by adult brook trout, as it currently occurs. Migrations will not be possible, but more important, the alteration of riverine habitat to reservoir conditions will destroy resources used year round by Nelson River trout. It is unlikely that the reservoirs will provide suitable rearing conditions for the trophy-size Nelson River brook trout, therefore a component of the population will be lost.

3. Destruction of riverine habitat within the Nelson River will result in fewer trophy-size brook trout in the Limestone River population. The availability of Nelson River habitat reduces intraspecific competition in the Limestone River and provides resources which allow growth of large fish.

RECOMMENDATIONS

1. Monitoring studies conducted over the past several years should be continued annualy to document changes in the brook trout populations of the Nelson River system as generating stations are constructed.

2. Upon completion of the Limestone Generating station, adult brook trout within the Limestone Forebay should be radio-tagged and monitored to identify movements within the reservoir and its' tributaries, and to determine preferred habitat under reservoir conditions.

3. Efforts should be made to maintain cover (trees and shrubs) in areas to be inundated by reservoir formation. Flooded trees and shrubs in creek mouths will increase the diversity of reservoir habitat and provide cover for juvenile or adult brook trout. Such areas may also increase primary productivity within the reservoirs.

PART VI

BROOK TROUT MONITORING

PART VI

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INTRODUCTION

Monitoring of brook trout within the Nelson River system was initiated several years ago to provide background information on stocks and habitat which will be affected by hydroelectric development. Continued monitoring during and following development will allow assessment of impacts on brook trout, as they occur. The knowledge which is gained from studies during current developments will be valuable in assessing potential impacts of future developments, and will provide a scientific basis upon which preventative, mitigative or enhancement measures may be planned.

Monitoring studies include: 1) juvenile brook trout stream utilization in the Conawapa Forebay, 2) larval brook trout drift in tributaries of the Limestone Forebay and Limestone River, and 3) brook trout spawning in tributaries of the Limestone Forebay and Limestone River. Each of these studies was continued in 1989. In addition, adult brook trout Floy tagging for habitat-use information, and fin sampling for anadromy determination, were continued during all monitoring studies. Results are presented within and discussed with comparison to previous years where appropriate.

METHODS

Stream Utilization

In 1989, as in the previous 3 years, the same 15 sites on 5 Nelson River tributaries were electrofished. These electrofishing sections on Moondance, Beaver, Swift, Tiny and Goose creeks are described in Swanson and Kansas (1987) (Figure 1). As in 1987 and 1988, the same three sites were electrofished on CN Creek in 1989 (Figure 1). The unnamed creek "15 Creek", first electrofished in 1988, was sampled at the same three sites in 1989 (Figure 1).

Electrofishing in previous years has snown that utilization of streams by juvenile brook trout may best be determined in early to mid-August. Electrofishing was conducted between the 10th and 15th of August, 1989 on most streams. Moondance Creek was electrofished on August 1-2 and 17-18, before and after a stream crossing was constructed over the creek. It was thought that some change in numbers of trout might occur due to construction of the crossing.

As in previous years, the entire length (100 m) of each electrofishing section was sampled from the top to a seine at the bottom (Swanson and Kansas 1987). If portions of the section could not be sampled, they were recorded to allow accurate determination of area sampled. Three electrofishing passes were performed in each stream, to collect data for removal-technique population estimation (Ricker 1975). Catch per unit of effort (CPUE) in numbers and weight were calculated and used for comparisons.

Lengths and weights of all brook trout captured were recorded. Those over 17 cm in length were Floy tagged and a sample of scales

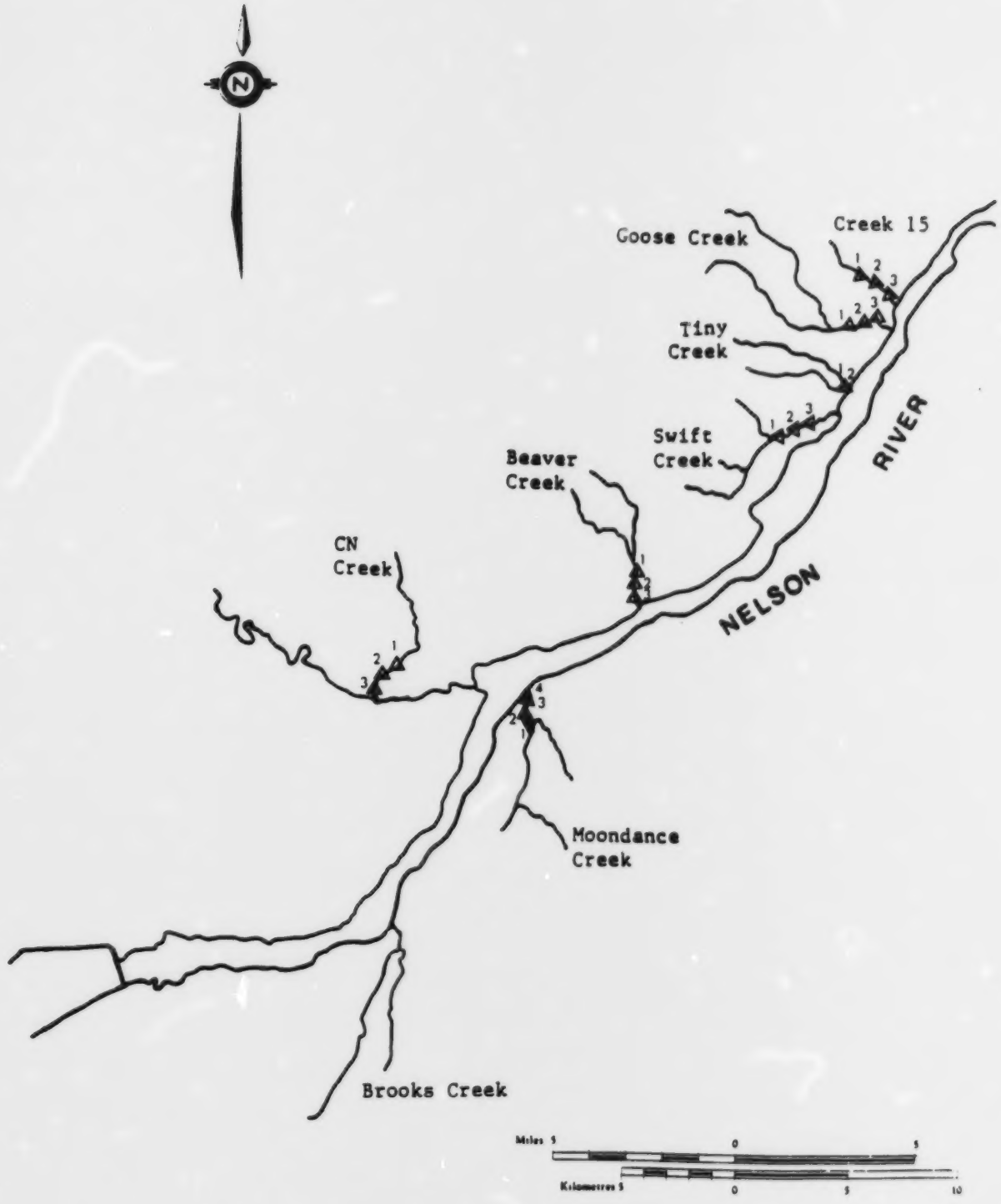


Figure 1. Locations of electrofishing sites for stream utilization studies in the Conawapa Forebay, 1989.

was removed for age determination. Other species captured were recorded by number; these data will be presented in an addendum to this report. Whenever possible, all fish were released unharmed.

As in the previous two years, additional electrofishing was conducted in a 400 m section of CN Creek for mark-recapture population estimation. The site is located downstream of electrofishing section 3, near the spawning area. Mark-recapture estimates were calculated by modified Petersen and modified Schnabel techniques (Ricker 1975). Recaptures were assumed to be Poisson in nature, therefore 95% confidence intervals were determined from confidence limits for Poisson variables in Ricker (1975). Fork lengths for use in length-frequency analyses were recorded from each captured trout.

Larval Drift

As in previous years, larval brook trout drift was monitored in spring of 1989 at the same sites in three Limestone River and three Limestone Forebay spawning tributaries. The Limestone River tributaries were 12-Mile, 9-Mile and CN creeks (Figure 2). The Limestone Forebay tributaries were Sky Pilot, Leslie and Wilson creeks (Figure 2).

In each stream, two stationary drift traps were installed as described in Swanson and Kansas (1987). The traps were placed side-by-side in water of manageable depth and velocity. In 12-Mile, 9-Mile, Sky Pilot, and Wilson creeks a third drift trap was floated in the fastest velocity by means of guys attached to shore. These floating drift traps were installed for comparison of numbers

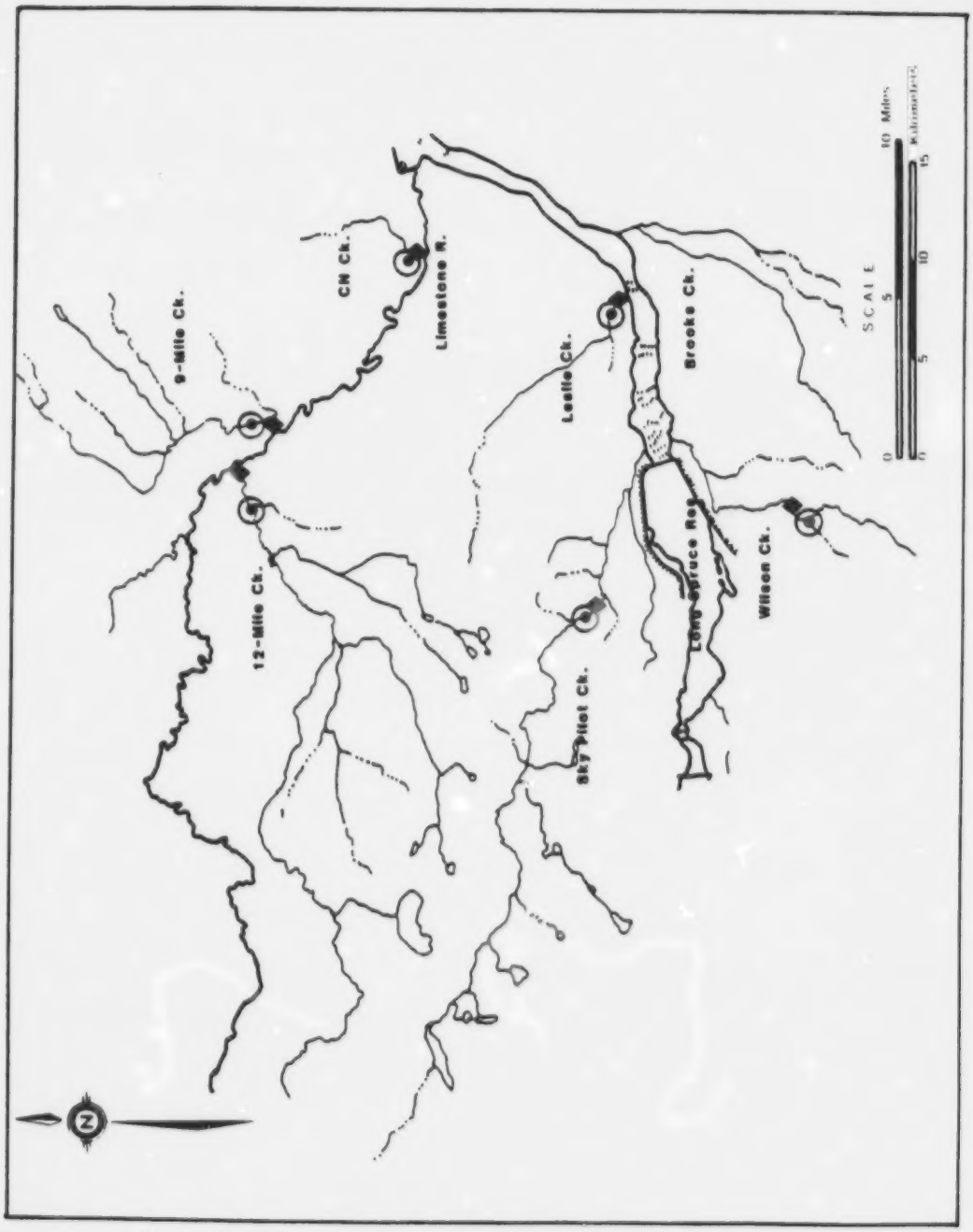


Figure 2. Locations of larval drift traps (diamonds) and known brook trout spawning areas (circles), 1989.

of fry drifting in fast verses slow water.

Traps were checked daily through the study period (May 13 to June 30). All debris in each trap was collected and sorted; all brook trout were enumerated. Before the traps were checked, velocity was measured daily at the mouth of each trap using a hand-held Price current meter. Velocity measurements were used to calculate volume of flow through traps, which was in turn used in CPUE determinations. On a few occasions when the velocity meter was not available, velocity was estimated as the mean of measurements on the day before and the day following.

A staff gauge was maintained within each stream during operation of the drift traps. Each 2-m-long gauge was bolted to a metal post which had been embedded in the stream bed. When receding water levels necessitated relocation of the gauge to deeper water, stage was measured before and after relocation to maintain continuity of recordings. Daily stage measurements were estimated to the nearest millimetre by eye. Discharge was measured on at least three occasions in each stream using the Mid-section method, as described in Nielsen and Johnson (1983). Velocities for discharge calculation were measured using the hand-held Price current meter. Stage-discharge relationships were established for each of the study streams from these data and used to estimate discharge from staff gauge records for each day during trap operation.

Temperatures were recorded during drift trap operation by means of Ryan Instruments 90-day thermographs located near the traps in each stream.

Spawning Populations

In fall of 1989 two-directional counting fences were used to sample adult brook trout in two Limestone Forebay tributaries: Sky Pilot and Wilson creeks, and two Limestone River tributaries: 9-Mile and 12-Mile creeks (Figure 3). The fences were operated from September 7 until ice conditions began to hamper efficiency, October 16-18. This period was chosen in order to sample brook trout migrating downstream following spawning. Previous years of fence operation have shown that the most accurate surveys of spawning brook trout were obtained from the downstream migration between mid-September and late October.

Fences were checked twice daily on all streams except 12-Mile, which was checked only once each day due to access restraints. Each brook trout captured was weighed (g) and measured (fork length, mm), a scale sample was removed for age determination, a Floy spaghetti tag was attached, and the fish was released to continue on in the direction it was travelling when captured. The date and time of capture, as well as direction of travel (upstream or downstream), were recorded. Water temperatures were recorded by thermographs (Ryan Instruments Model J; 90-days) during the period of fence operation. Each time a fence was checked, debris which had accumulated was removed and the structure was examined and reinforced to ensure that it was functioning efficiently.

Floy Tagging and Strontium Analysis

As in previous years each brook trout longer than 17 cm in

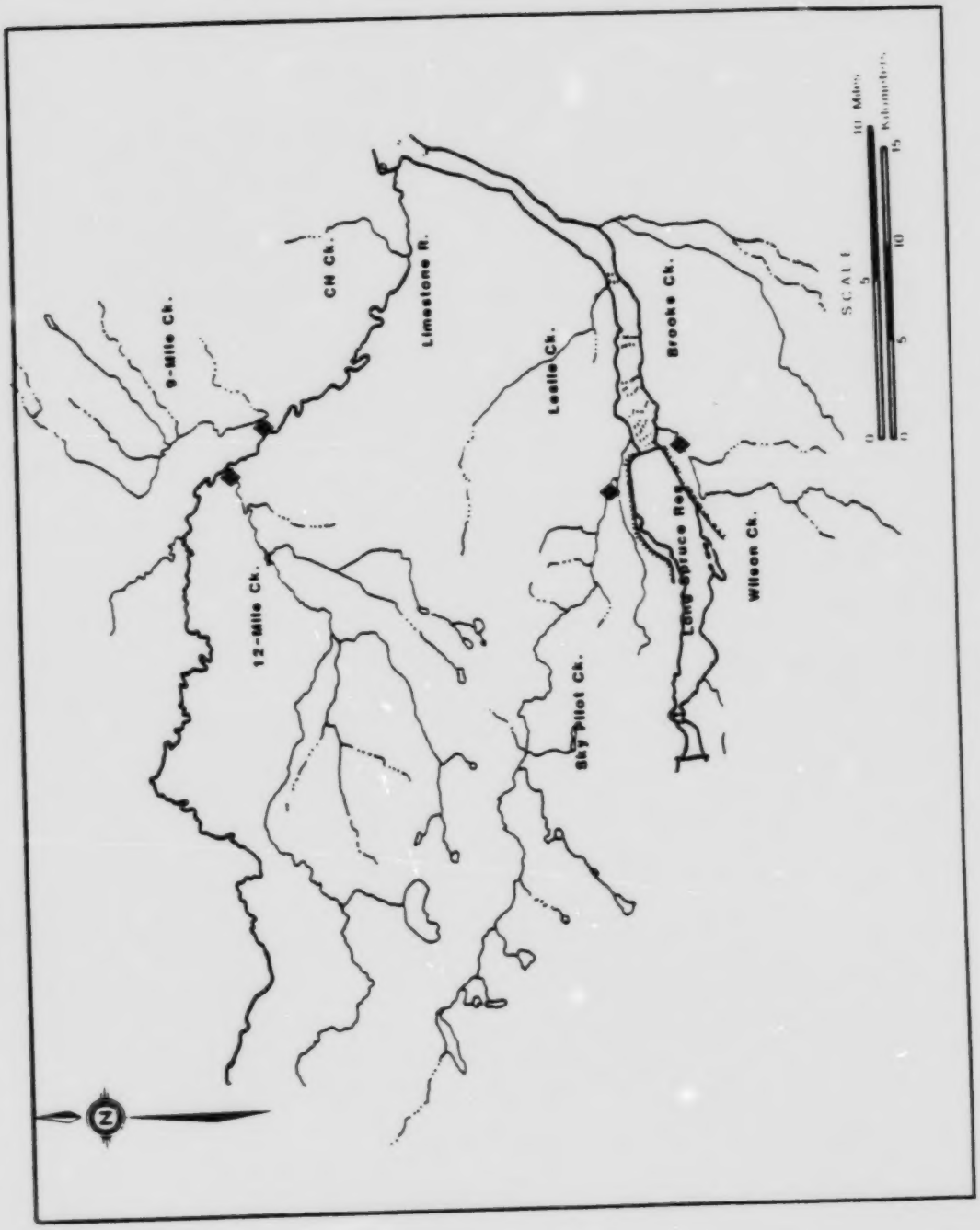


Figure 3. Locations of fall brook trout fences, 1989.

fork length was marked with a numbered Floy spaghetti tag. Tags were anchored between interneural spines at the posterior origin of the dorsal fin. When a fish was recaptured the location, date and tag number were recorded, and the fish was weighed, measured and released.

The left pelvic fin of all brook trout greater than 17 cm long was removed for strontium analysis; the mark was used to assess tag loss. The fin samples were analysed as described in Swanson and Kansas (1987). A strontium level greater than 215 ug/l was used to indicate that a fish had spent some time in marine conditions (Swanson and Kansas 1987).

RESULTS AND DISCUSSION

Stream Utilization

Table 1 contains a record of electrofishing effort, numbers of brook trout caught, and CPUE in each sampling section. The majority of trout captured were young-of-the-year. As in previous years the streams in which spawning occurs, Moondance and CN creeks, provided greater CPUE than the other streams. They harboured greater numbers of juvenile brook trout during summer than the smaller Conawapa Forebay streams where spawning does not occur. Only a few trout are captured in these small nursery streams each year.

Since few trout were captured during three electrofishing removal passes in sampling sections of the nursery streams, populations in these sections must be very close to the numbers captured. A maximum of three trout was captured in any one section of Beaver, Swift, Tiny, Goose and 15 creeks (Table 1). Despite the small populations, these streams provide important rearing habitat for young-of-the-year which have drifted out of spawning streams and into the Nelson River. These fish migrate upstream from the Nelson River into the more favorable habitat of the small streams, and remain there until fall. The nursery streams are too shallow to provide much suitable overwintering habitat; it is thought that most trout move downstream to the Nelson River in fall (Swanson and Kansas 1987). The downstream movement may be triggered by decreasing temperatures in fall, which stress brook trout until they drift to deep slow areas (Cunjak 1988).

Table 1. Summary of electrofishing effort and catch in Conawapa Forebay streams, 1989.

Section	Date	Area (m^2)	Seconds	No. Trout	Wt. Trout (g)	CPUE (no./m^2/sec)	CPUE (g/m^2/sec)
M1	Aug. 2	632.7	1685	12	202	0.0000112	0.0001894
M2	Aug. 2	655.5	2348	40	349	0.0000259	0.0002267
M3	Aug. 1	514.5	3054	46	955	0.0000292	0.0006077
M4	Aug. 1	688.2	1875	50	1198	0.0000387	0.0009284
B1	Aug. 11	314.5	645	0	0	0	0
B2	Aug. 11	308.2	647	0	0	0	0
B3	Aug. 11	211.8	638	1	55	0.0000074	0.000407
S1	Aug. 15	529.1	647	1	10	0.0000029	0.0000292
S2	Aug. 15	344.4	456	0	0	0	0
T1	Aug. 13	192.1	430	0	0	0	0
T2	Aug. 13	230.9	474	0	0	0	0
G1	Aug. 12	586.4	1389	2	508	0.0000024	0.000623
G2	Aug. 12	440	1141	3	21	0.0000059	0.0000418
G3	Aug. 12	490	1249	0	0	0	0
CN1	Aug. 10	234.5	818	0	0	0	0
CN2	Aug. 10	188.2	426	5	61	0.0000623	0.0007608
CN3	Aug. 10	160.9	763	10	295	0.0000814	0.0024029
F1	Aug. 16	146.4	758	0	0	0	0
F2	Aug. 16	143.3	411	1	6	0.0000169	0.0001018
F3	Aug. 16	311.8	922	0	0	0	0
M1	Aug. 18	600.9	991	8	382	0.0000134	0.0006414
M2	Aug. 18	610.9	1216	33	229	0.0000444	0.0003082
M3	Aug. 17	502.7	1905	108	2281	0.0001127	0.0023818
M4	Aug. 17	583.6	1674	63	1370	0.0000644	0.0014023

M = Moondance, S = Swift, T = Tiny, G = Goose, CN = CN, F = Fifteen, B = Beaver

In each sampling section of CN Creek, the numbers of brook trout captured by electrofishing are probably very close to the total population (Table 1). No trout were captured in the three passes in section CN1. In section CN2, two trout were captured on the first pass, three on the second and none on the third, for a total of five. In section CN3, four trout were captured on the first pass, three on the second and three on the third, for a total of ten. Electrofishing passes in the sample sections of Moondance Creek produced greater numbers of brook trout (Table 1), however these data are not suitable for calculation of removal-technique population estimates.

A comparison of CPUE between years in spawning streams, nursery streams, and in both categories combined is presented in Table 2 and Figure 4. Nursery streams include Beaver, Swift, Tiny and Goose creeks. Fifteen Creek has been omitted for consistency, since it was not sampled in 1986 or 1987. The spawning category includes only Moondance and CN creeks. The number of brook trout captured per unit of effort in nursery streams appears to have increased in 1989 (Figure 4). However, since the actual number of fish captured in these streams each year is very low, such an increase in CPUE is more likely due to a decrease in effort in 1989, than an increase in number of fish (Table 1). For example, numbers of brook trout captured in Beaver Creek decreased from three in 1988 to one in 1989; in Swift creek one trout was captured in each of 1988 and 1989; in Tiny Creek two trout were captured in 1988 while none were captured in 1989; and, in Goose Creek no trout were captured in 1988 while five were captured in 1989. The weight

Table 2. Electrofishing catch per unit effort in spawning and nursery streams in the Conawapa Forebay, 1986-1989.

	Frequency (no./m^2/s) x 10^{-7}			
	1986[a] Sept. 11-Sept. 17	1987[b] Aug. 14-Sept. 14	1988 Aug. 4-Aug. 14	1989 Aug. 1-Aug. 15
Nursery	0.9	1.0	1.0	2.5
Spawning	14.0	39.0	23.0	48.3
Combined	1.5	6.0	4.0	13.5
	Weight ($g/m^2/s$) x 10^{-5}			
Nursery	0.8	0.4	0.06	2.1
Spawning	13.7	5.2	4.8	9.1
Combined	1.3	0.9	0.9	2.9

Nursery = Beaver, Swift, Tiny and Goose creeks.
Spawning = Moondance and CN Creeks.
a - CN Creek Sections not sampled in 1986.
b - CN Creek Section 1 not sampled in 1987.

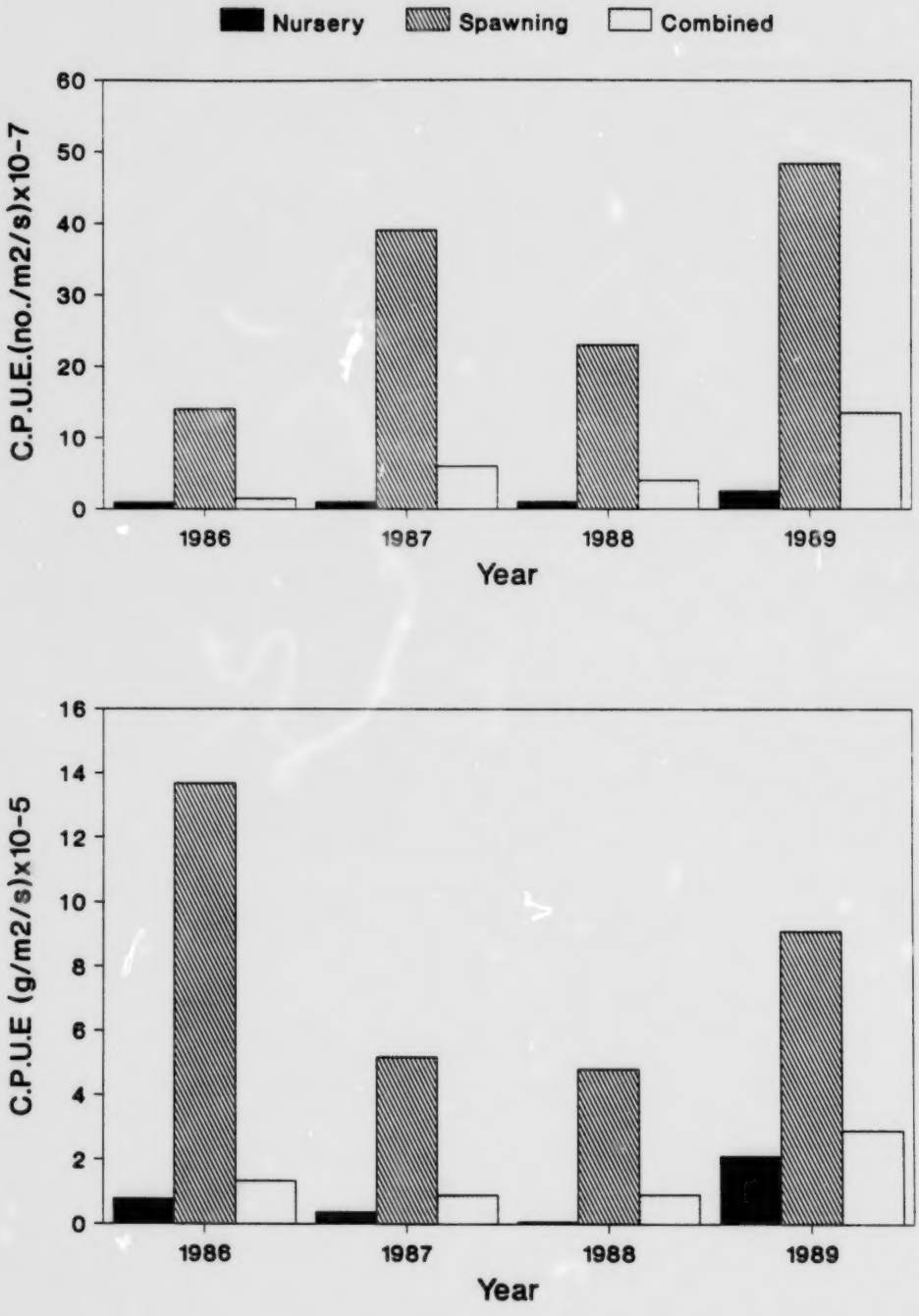


Figure 4. Electrofishing catch per unit effort (number and weight) for spawning and nursery streams in the Conawapa Forebay, August 1-15, 1989.

of brook trout captured per unit of effort in nursery streams increased to a much greater degree than did number in 1989 (Table 2, Figure 4). This was the result of one large trout captured in Goose Creek, which has biased the data.

In spawning streams, the number of trout captured per unit of effort in 1989 is notably greater than that in previous years (Table 2, Figure 4). When CPUE in 1989 and 1988 are compared within each of the two spawning streams, it is apparent that the increase stems from Moondance Creek only. The CPUE for CN Creek in 1989 ($0.0000127/m^2/s$) is almost identical to that in 1988 ($0.0000128/m^2/s$). The CPUE for Moondance Creek in 1989 ($0.0000066/m^2/s$) is double that in 1988 ($0.0000029/m^2/s$). Actual numbers of trout captured increased from 51 in 1988 to 148 in 1989, while area sampled decreased (2962 m^2 in 1988; 2491 m^2 in 1989) and time sampled increased (6047 s in 1988; 8962 s in 1989). The weight per unit of effort in spawning streams in 1989 is correspondingly higher than in previous years, with the exception of 1986, which was biased by the capture of one adult trout in Moondance Creek (Table 2, Figure 4).

The population of young-of-the-year brook trout rearing in Moondance Creek in 1989 was greater than in 1988. In 1987, large numbers of young-of-the-year brook trout were also found in Moondance Creek (Swanson et al. 1988), as reflected in the 1987 CPUE for spawning streams (Table 2, Figure 4). These notable increases in trout production may be related to favorable environmental conditions, such as mild incubation temperatures in winter. Trout production may also be influenced by a large beaver

dam on Moondance Creek which increases pool volume and provides a sanctuary from peak spring flows which could otherwise disperse trout out of the creek (Swanson et al. 1988).

Electrofishing in Moondance Creek following the construction of a temporary crossing (culverts and fill) produced markedly different CPUE than prior to construction. The CPUE over all sections doubled between August 1-2 (0.0000066 trout/m^2/s) and August 17-18 (0.0000160 trout/m^2/s). Individual CPUE for each electrofishing section shows that the increase was largely in section M3 (Figure 5). The crossing was constructed approximately 20-m downstream of an old and impassable beaver dam between the upstream (M1-M2) and the downstream (M3-M4) electrofishing sections. The beaver dam is a barrier to fish movement, except possibly in spring freshet. Because of this barrier, construction of the crossing could not have affected brook trout populations in the two upstream sections, M1 and M2. CPUE in M1 was similar on both sampling occasions (Figure 5), but appears to have increased in M2 (Figure 5). The lower CPUE calculated for M2 on August 2 is the result of greater electrofishing effort on August 2 than on August 18, while almost the entire population of trout was captured on each occasion (Table 1).

The increased CPUE in section M3, downstream of the crossing, is valid in indicating an increased population. Prior to completion of the crossing, a large number of juvenile brook trout was seen at the base of the beaver dam upstream of section M3 (R. Labossiere, N.R.O., Sundance, personal communication). Upon completion of the crossing, these fish were observed travelling

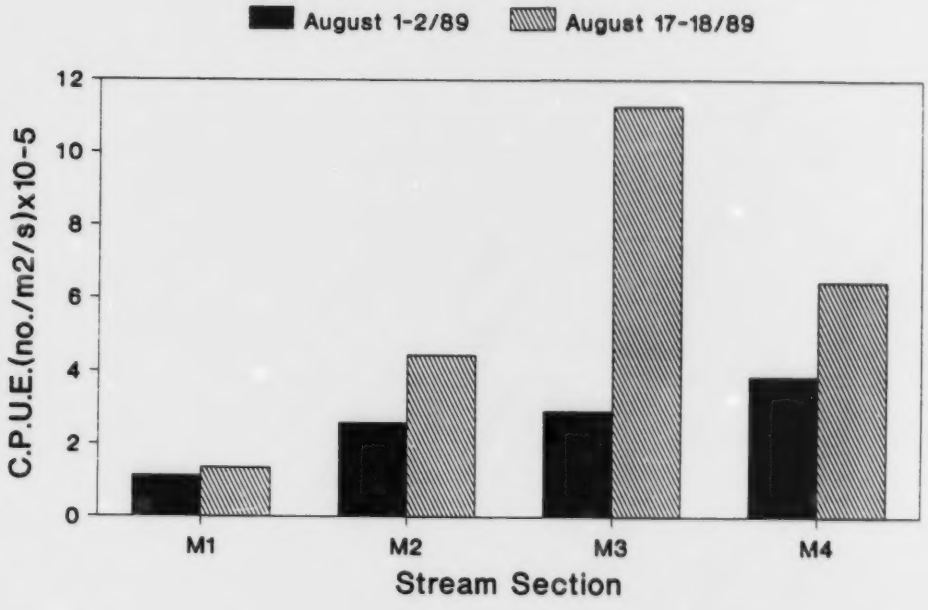


Figure 5. Number of brook trout captured per unit of electrofishing effort in the four sections on Moondance Creek, before (August 1-2) and after (August 17-18) construction of a stream crossing in 1989.

downstream through the culverts and into section M3. It is likely that many of these fish remained in section M3 and were sampled there during electrofishing on August 17. It is also likely that some fish moved further down into M4 resulting in the increased CPUE for that section on August 17 (Figure 5).

Length-frequency distributions (10-mm length intervals) of brook trout captured in a 400-m section of CN Creek in the past three years are presented in Figure 6. Lengths are from those fish captured by electrofishing during sampling for population estimation. One large fish (362 mm) which was captured in 1988 has been omitted from the figure for clarity in presentation. Data from two sampling dates are presented for 1989. The total number of fish measured for each data set is as follows: August 19, 1987, n = 41; August 10, 1988, n = 121; August 21, 1989, n = 131; and August 31, 1989, n = 87.

In length intervals greater than 100 mm, the percentages of each sample are small and distributed similarly (Figure 6). These data represent the adults and large juveniles that inhabit CN Creek in August. The remainder of each sample consists of young-of-the-year. The length that young-of-the-year achieve in their first summer varies somewhat between years (Figure 6). Growth may have been affected by many natural and anthropogenic influences such as temperature, or silt over food-producing substrate.

The mark-recapture estimates calculated from electrofishing in the 400 m section of CN Creek in the past three years are presented in Table 3. These estimates indicate that in 1988 and 1989 CN Creek supported populations of brook trout only half as large as

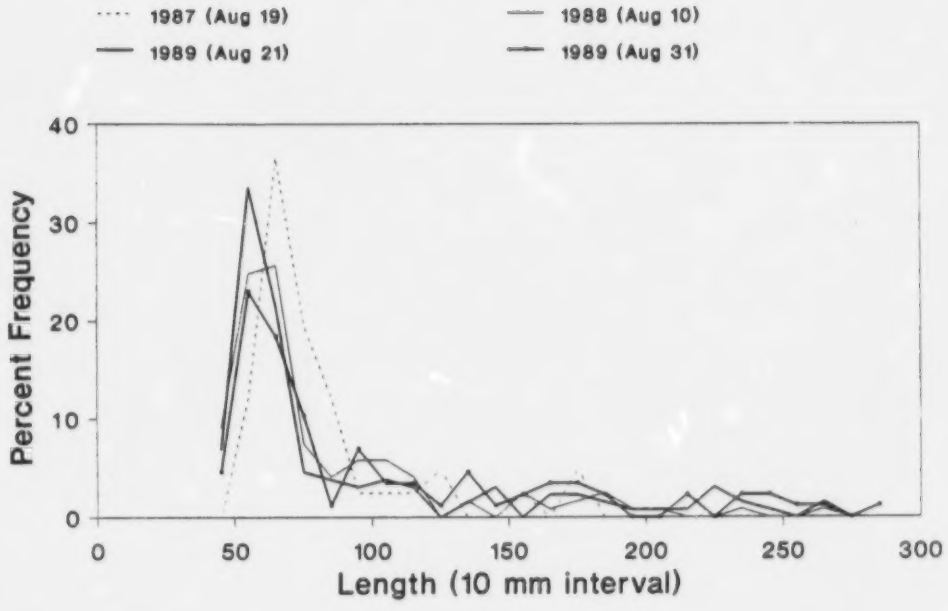


Figure 6. Length-frequency distributions of brook trout captured for population estimation in CN Creek; 1987, 1988 and on two occasions in 1989.

Table 3. Mark-recapture estimates and 95% confidence intervals for one 400-m long section of CN Creek in 1987, 1988 and 1989.

Year	Sample	Marks (M)	Total captures (C)	Recaptures (R)	Population estimate (N)	Confidence interval (95%)
1987	Modified Petersen (29/08/87)	91	72	9	671	367-1328
	Modified Petersen (02/09/87)	91	93	13	617	371-1094
	Modified Schnabel (combined 87 data)	--	--	22	652	424-962
1988	Modified Petersen (10/08/88)	68	60	11	351	200-678
	Modified Petersen (29/08/88)	68	19	5	276	105-627
	Modified Petersen (30/08/88)	87	26	10	216	120-440
	Modified Schnabel (combined 88 data)	--	--	26	282	200-428
1989	Modified Petersen (22/08/89)	83	66	18	296	191-481
	Modified Petersen (31/08/89)	83	50	13	306	183-542
	Modified Petersen (01/09/89)	120	48	19	296	194-474
	Modified Schnabel (combined 89 data)	--	--	50	302	230-404

that present in 1987. The smaller populations of both 1988 and 1989 are probably due to freezing and wash-out of the road crossing on CN Creek in spring of both years (Figure 7).

The crossing was installed in summer of 1986, and in the following winter and spring it did not create any flow problems. In March of 1988, due to difficulties in maintenance, the culverts at the crossing froze shut diverting the stream through the CN gravel pit and on into the Limestone River (Figure 7). During this period of diversion, flow in the downstream portion of CN Creek was negligible which would have decreased the amount of available habitat for emerging brook trout fry and other life-stages inhabiting this reach. As a result, these fish would likely have drifted out of the creek. The culverts were steamed open on May 15, 1988, at which time the downstream flow in CN Creek increased from 0.1 to 10.6 cubic metres per second. This sudden increase in flow may have further reduced the population by flushing more trout from the downstream reach (Elwood and Waters 1969).

In March of 1989, again due to problems with maintenance, the culverts once more froze shut (Figure 7). In this year, the spring freshet did not divert CN Creek, but washed out the crossing adding large amounts of sediment to the system. This sudden rush of turbid water likely flushed many trout out of the stream and deposited large amounts of silt and sand, decreasing both suitable habitat and benthic food production (Cordone and Kelly 1961; Elwood and Waters 1969; Alexander and Hansen 1986).

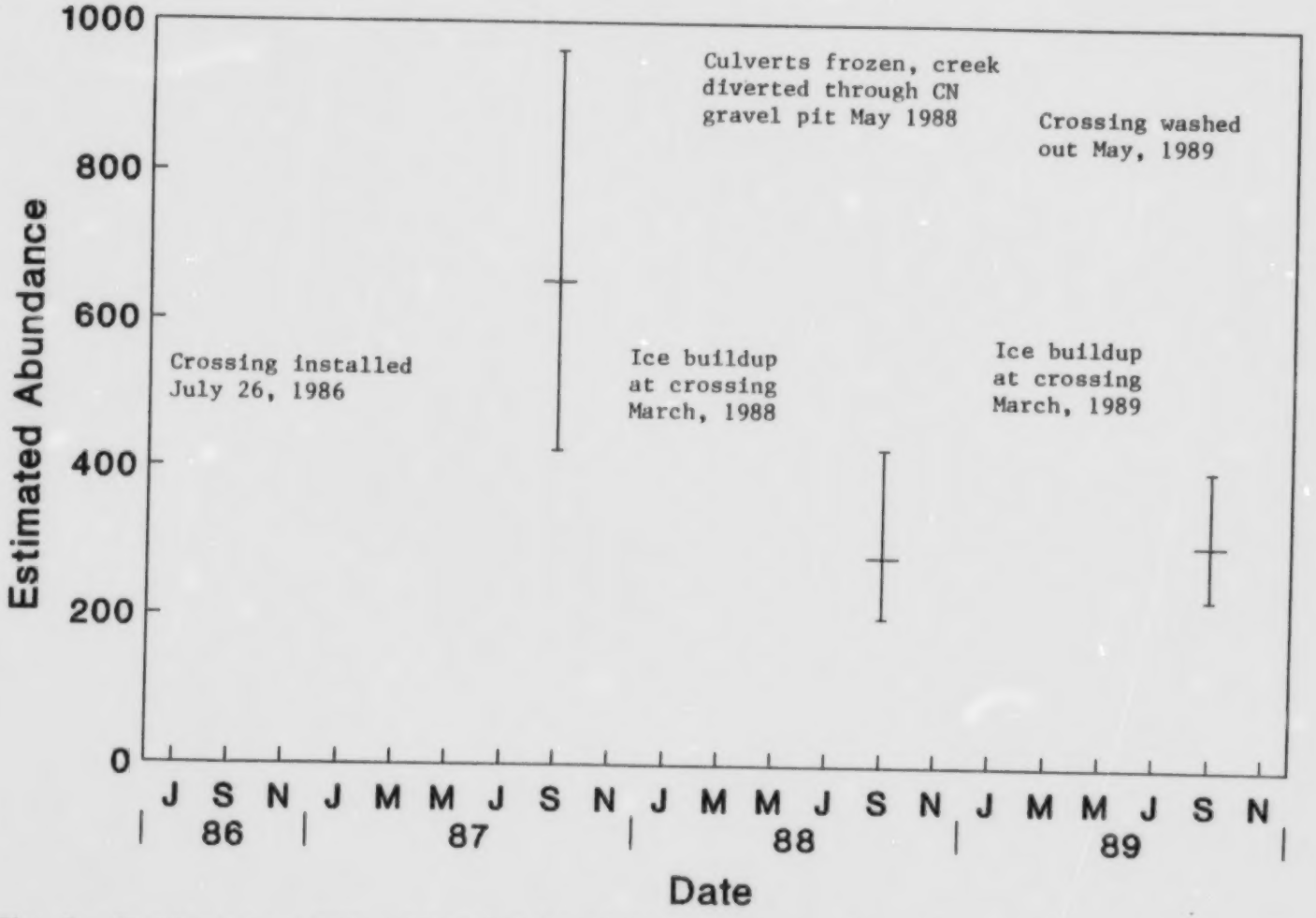


Fig. 7. Population estimates (Modified Schnabel) and 95% confidence intervals for a 400 m section of CN Creek, as sampled in 1987, 1988 and 1989. Significant influences on stream habitat are indicated at the appropriate dates.

Larval Drift

Numbers of brook trout larvae captured in drift traps each day are presented by stream in Figures 8 and 9. Daily catch per unit of effort in each stream is presented in Figures 10 and 11. Data are combined for side-by-side stationary traps. Data for 12-Mile Creek are not illustrated since no larvae were captured in stationary traps, and only two larvae were collected in the floating trap (one on May 21, 1989, CPUE = 0.00031 larvae/m^3/day; and one on June 1, 1989, CPUE = 0.00058 larvae/m^3/day). No larvae were captured in stationary traps in Wilson Creek. The floating trap in Wilson Creek collected only one larva; CPUE = 0.00048 larvae/m^3/day, May 19, 1989.

Comparison of catch data to previous years is difficult because efficiency of drift traps is dependent on discharge and also, it appears, on location in the stream. In CN Creek, for example, 25 larvae were collected in 1989 while 41 were collected in 1988. This difference is not due to greater numbers of larvae drifting in 1988, but to high trap efficiency during the period of extremely low flow in 1988 when CN Creek was diverted upstream by frozen culverts. In 9-Mile Creek, 75 larvae were captured in 1989 while only 21 were captured in 1988. The reason for this increase is unknown, however the drift trap location was changed in 1989 due to beaver activity. The beaver activity also prevented accurate measurement of stage and estimation of discharge, so it is not possible to determine whether trap efficiency may have been affected by a difference in discharge between 1988 and 1989.

Some consistencies have been noticed in the three years of

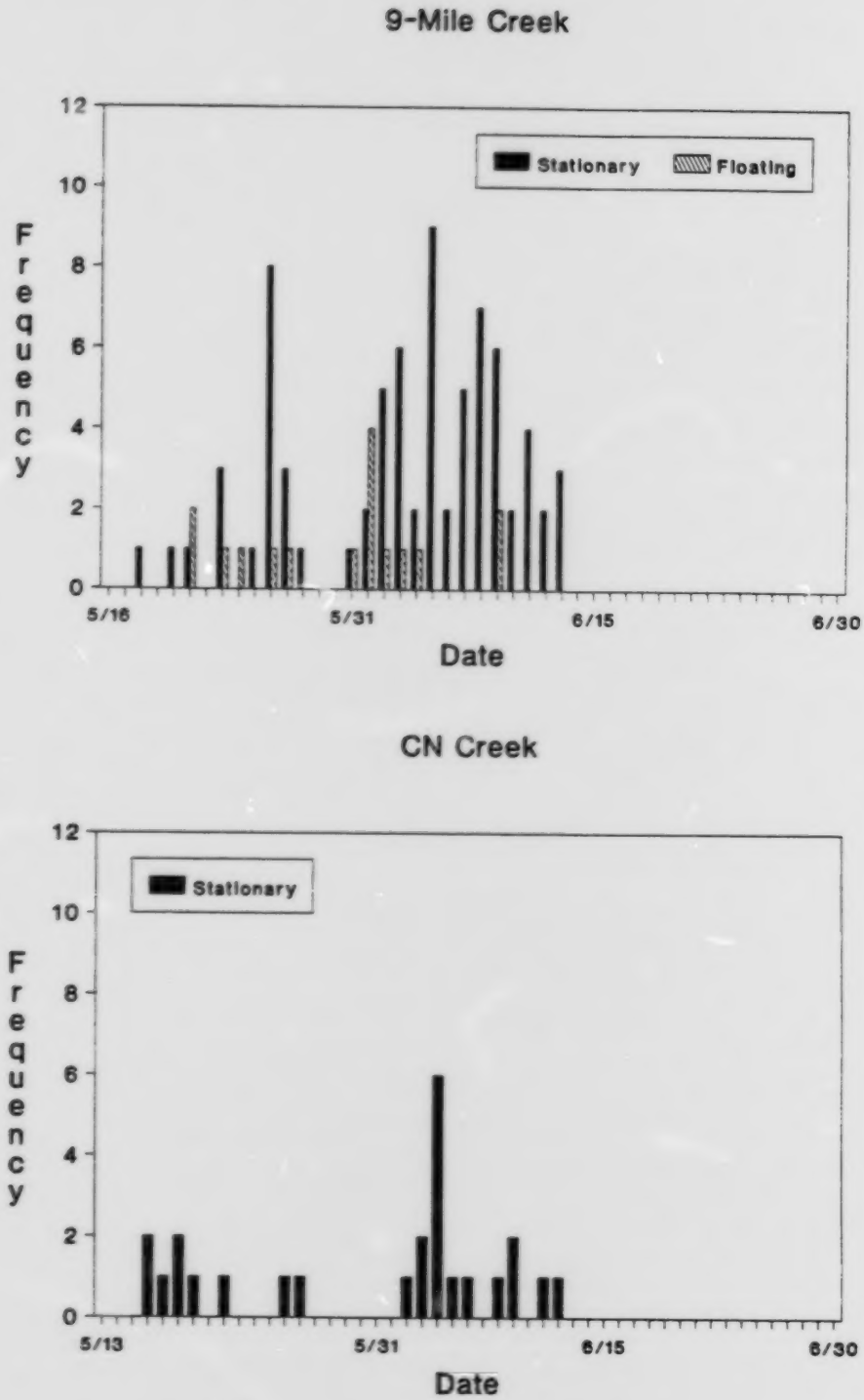


Figure 8. Numbers of brook trout larvae captured in drift traps each day in 9-Mile and CN creeks, 1989. A floating trap was not installed in CN Creek.

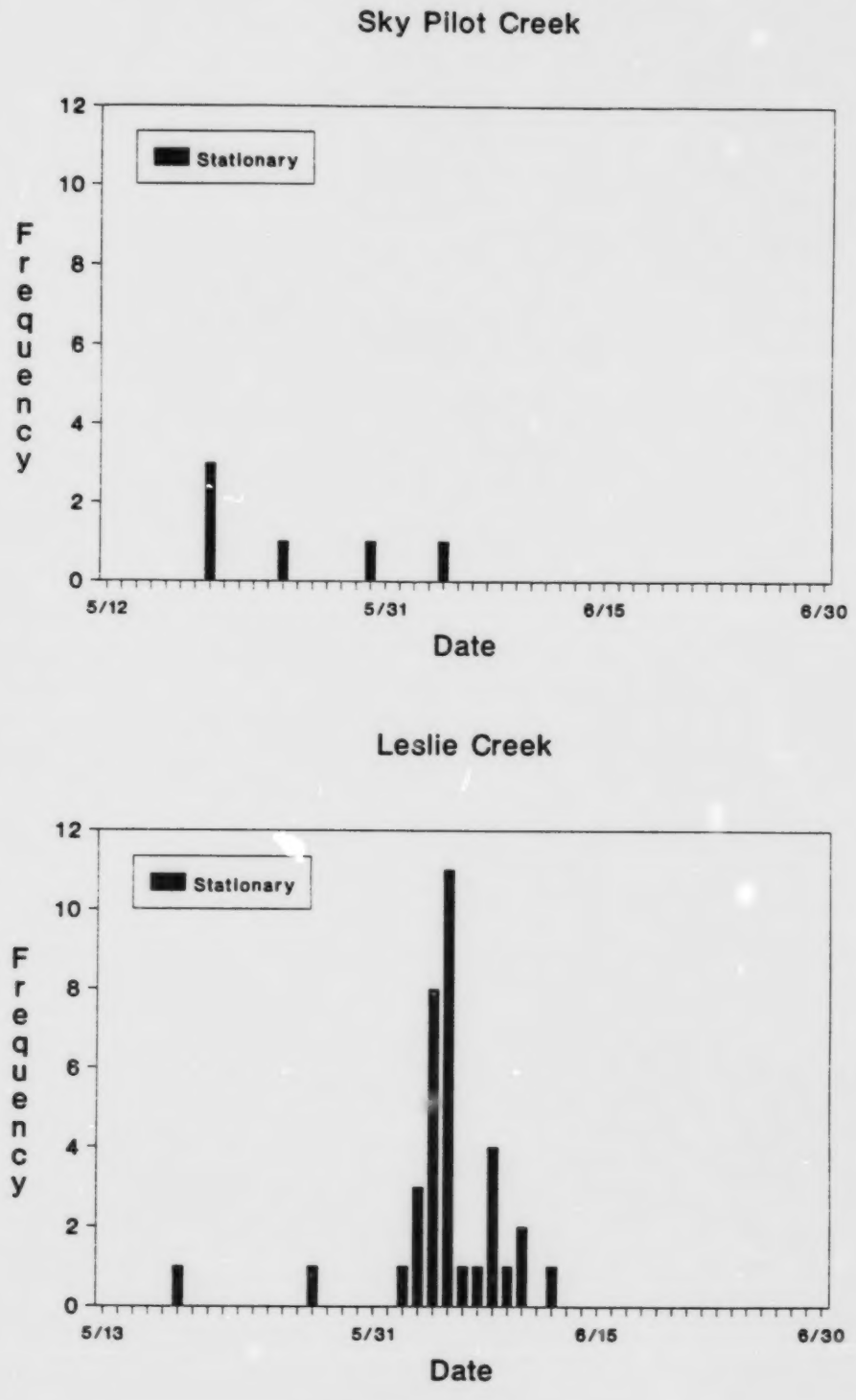


Figure 9. Numbers of brook trout larvae captured in drift traps each day in Sky Pilot and Leslie creeks, 1989. A floating trap was installed in Sky Pilot Creek (no larvae were collected); a floating trap was not installed in Leslie Creek.

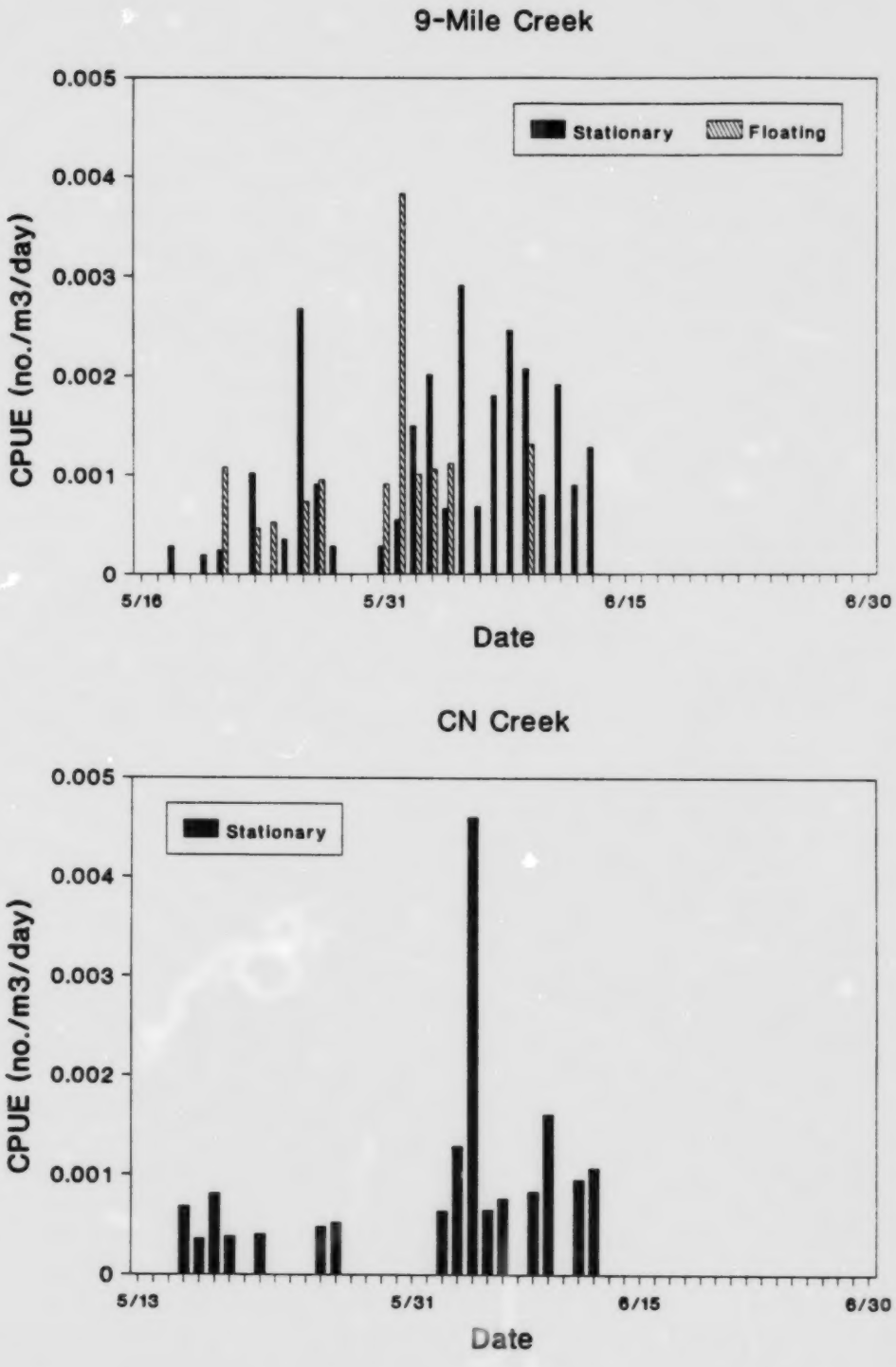


Figure 10. Daily catch per unit effort of brook trout larvae in drift traps in 9-Mile and CN creeks, 1989. A floating trap was not installed in CN Creek.

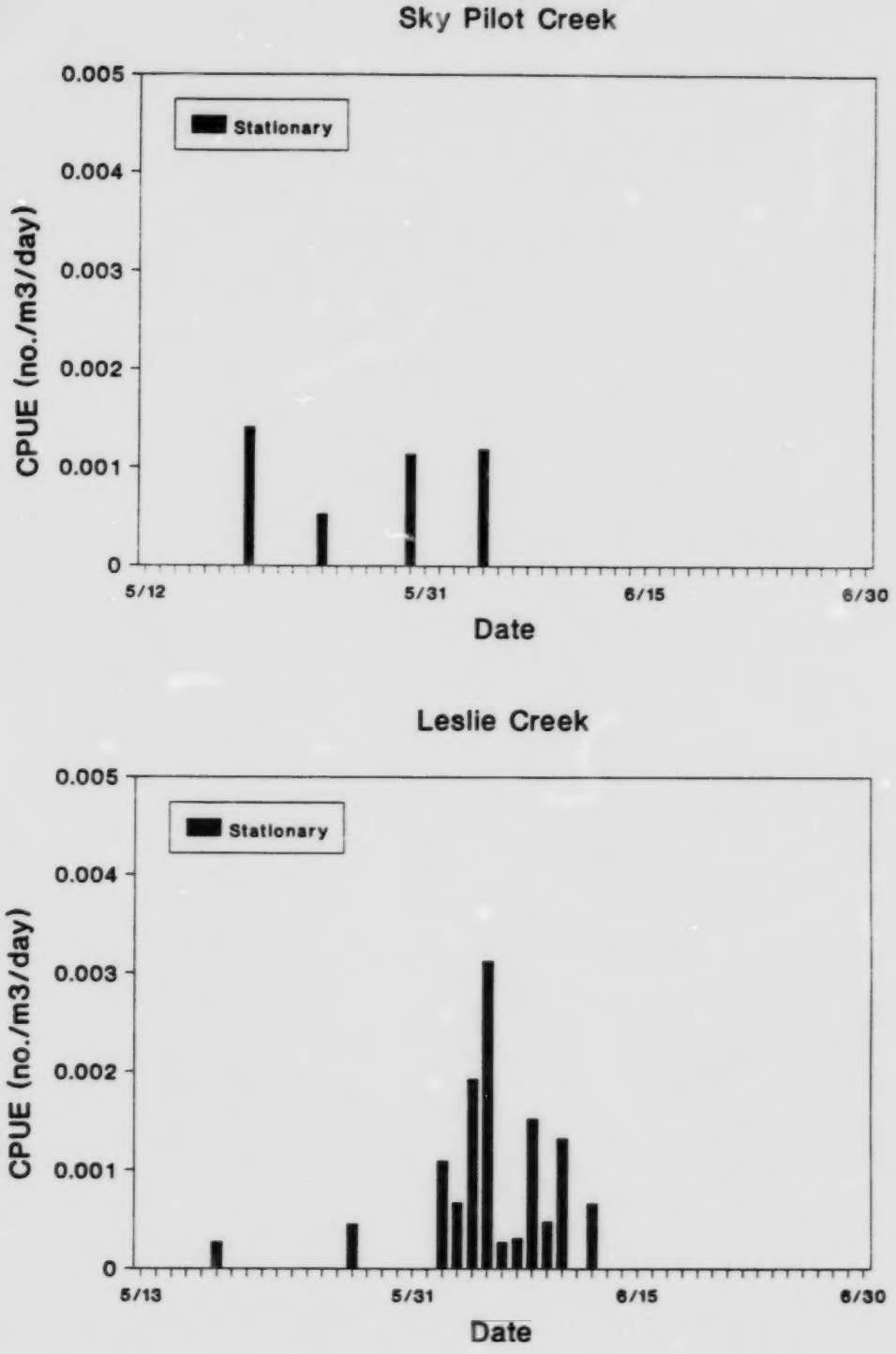


Figure 11. Daily catch per unit effort of brook trout larvae in drift traps in Sky Pilot and Leslie creeks, 1989. No larvae were collected in the floating trap in Sky Pilot Creek; a floating trap was not installed in Leslie Creek.

drift sampling. A good number of larvae have been captured each year in CN, Leslie and 9-Mile creeks. In 12-Mile Creek few if any larvae were captured in any year. These patterns may relate to the size, and therefore discharge, of these streams. Lower discharge allows a greater percentage of the flow to be sampled, therefore in small streams larvae are more consistently captured. In larger streams such as 12-Mile Creek few larvae are captured since they are sparsely distributed in the flow, and only a small portion of the total discharge is sampled. Catch in Sky Pilot and Wilson creeks in 1989 was low and corresponded with high discharge during this period. Daily records of discharge in each stream are presented in Figures 12, 13 and 14. High flows estimated in Sky Pilot and Wilson creeks in mid-May are not plotted because accuracy of the stage-discharge relationships is questionable at these extreme flows. It is sufficient to note that the change in flow during this period, as recorded by staff gauges, was a steady decline.

A close relationship between larval drift and temperature was apparent in 1989. During a four-day period in late May temperatures decreased markedly (Figures 15, 16 and 17) and catch of larvae in drift traps dropped to zero (Figures 8 and 9). The subsequent increase in temperature produced a sharp increase in catch.

Total daily drift in each stream was not estimated for 1989 since it is unlikely that the method used previously is valid. Total daily drift in 1988 was estimated by extrapolation of CPUE in stationary drift traps located near shore, to the entire discharge

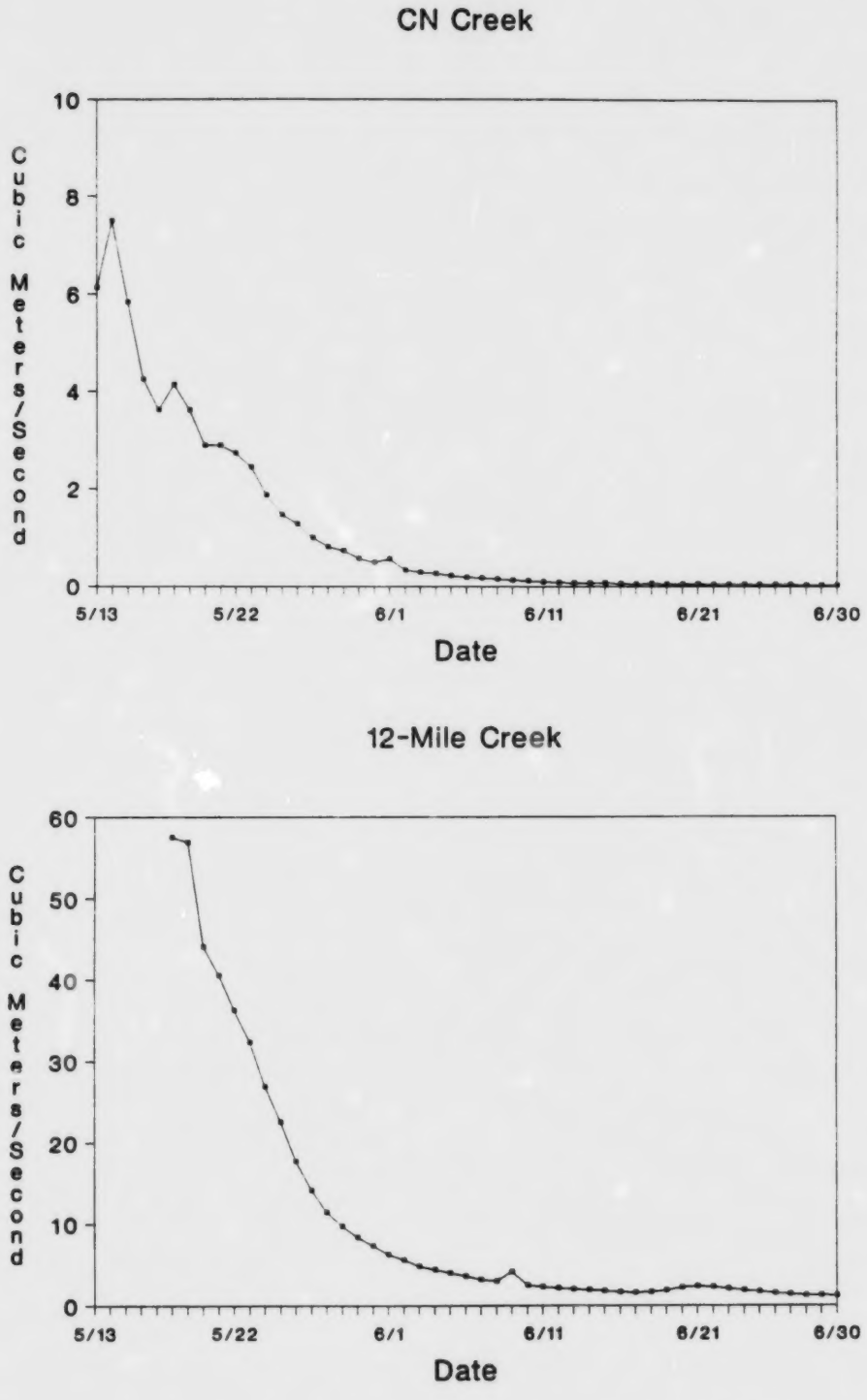


Figure 12. Daily records of discharge in CN and 12-Mile creeks during the drift sampling period, 1989.

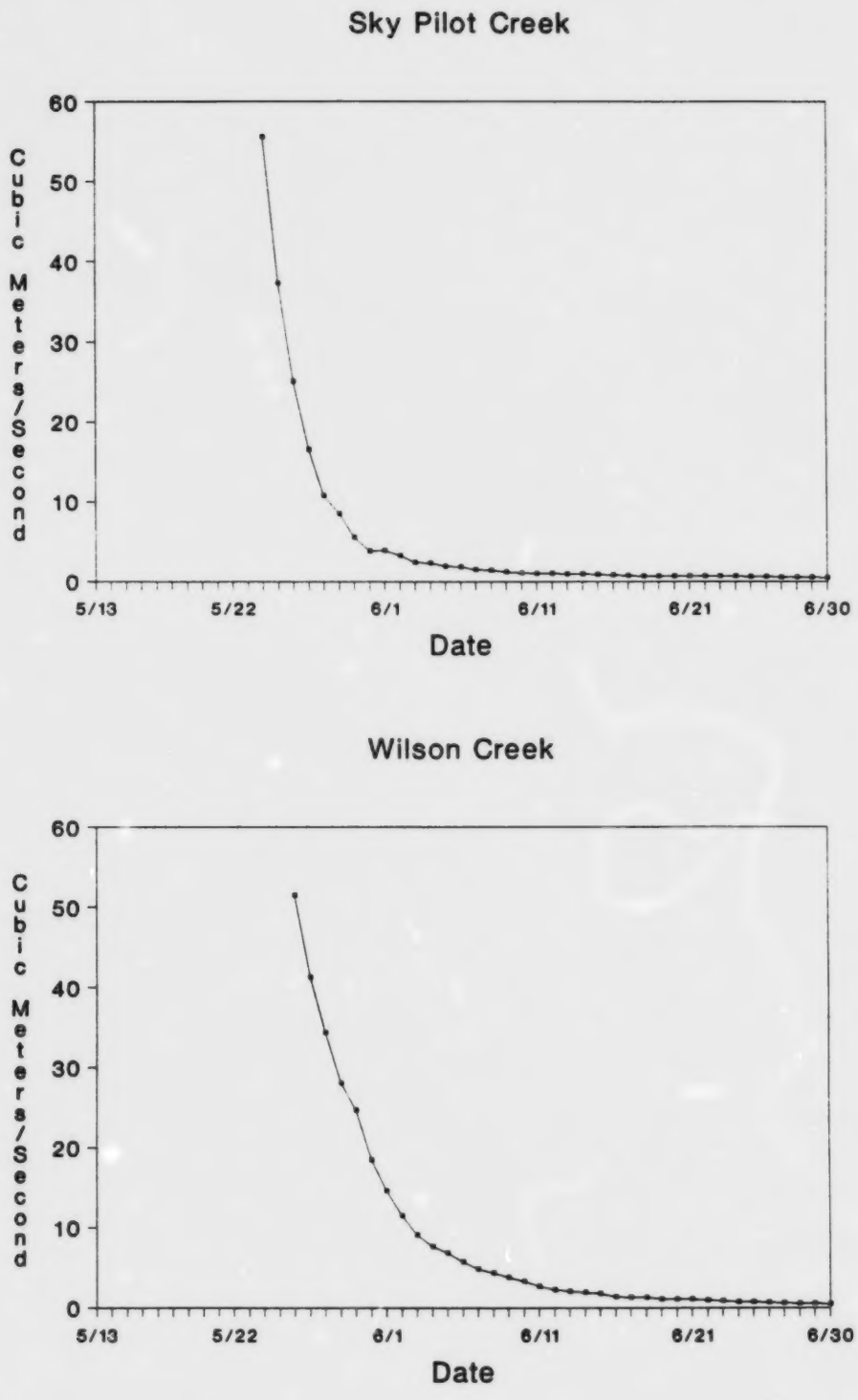


Figure 13. Daily records of discharge in Sky Pilot and Wilson creeks during the drift sampling periods, 1989.

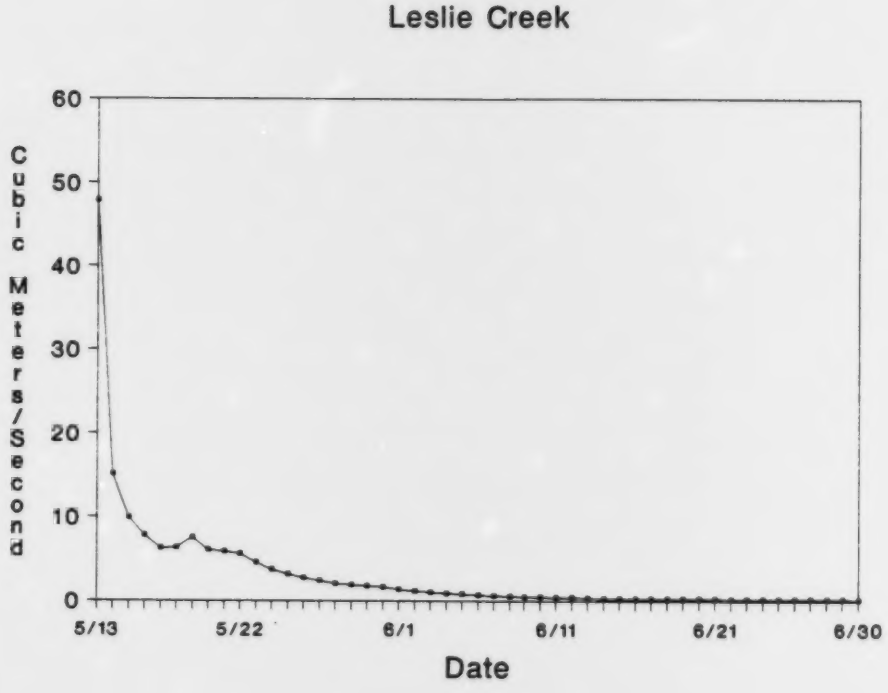


Figure 14. Daily record of discharge in Leslie Creek during the drift sampling period, 1989.

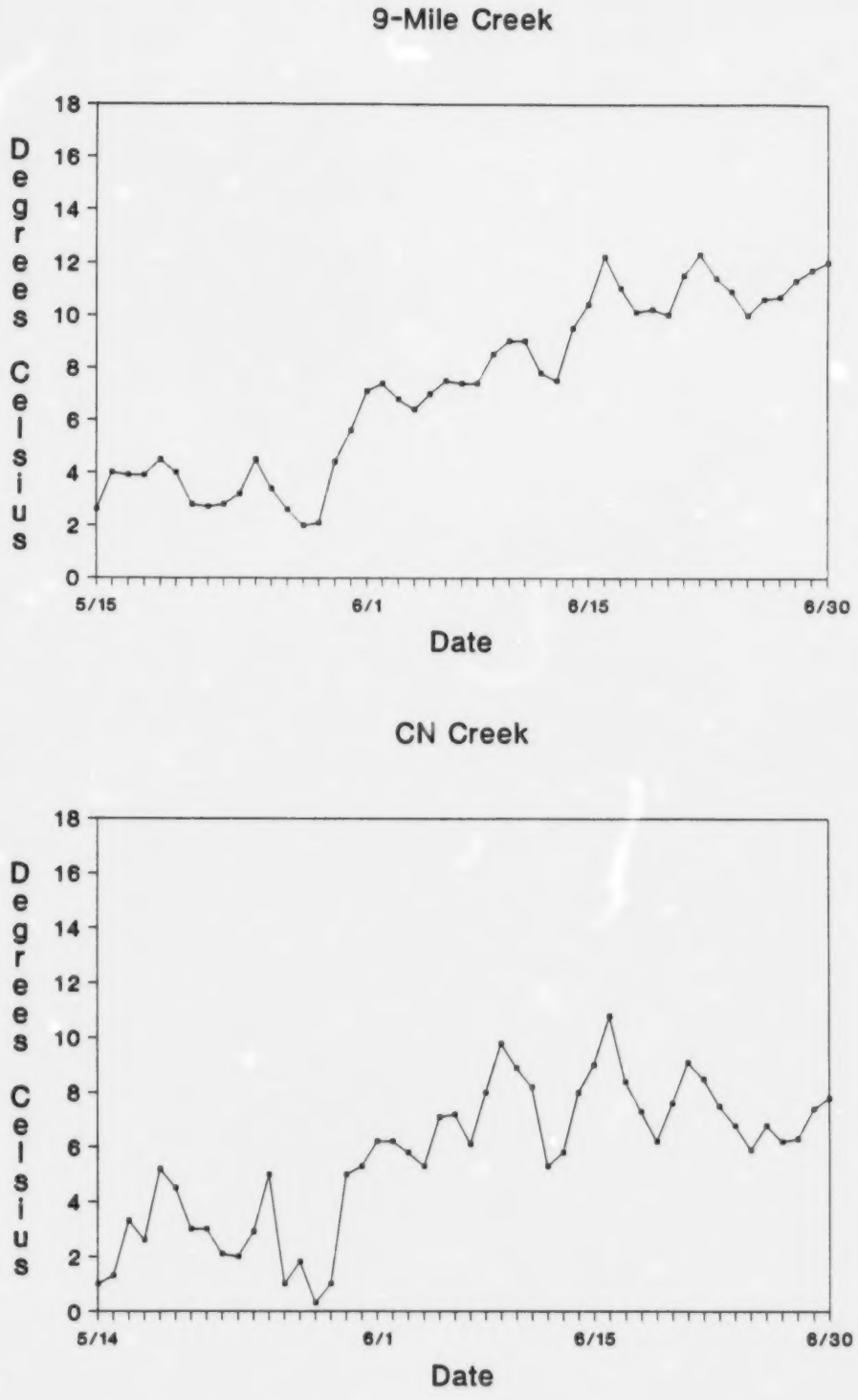


Figure 15. Daily records of temperature in 9-Mile and CN creeks during the drift sampling period, 1989.

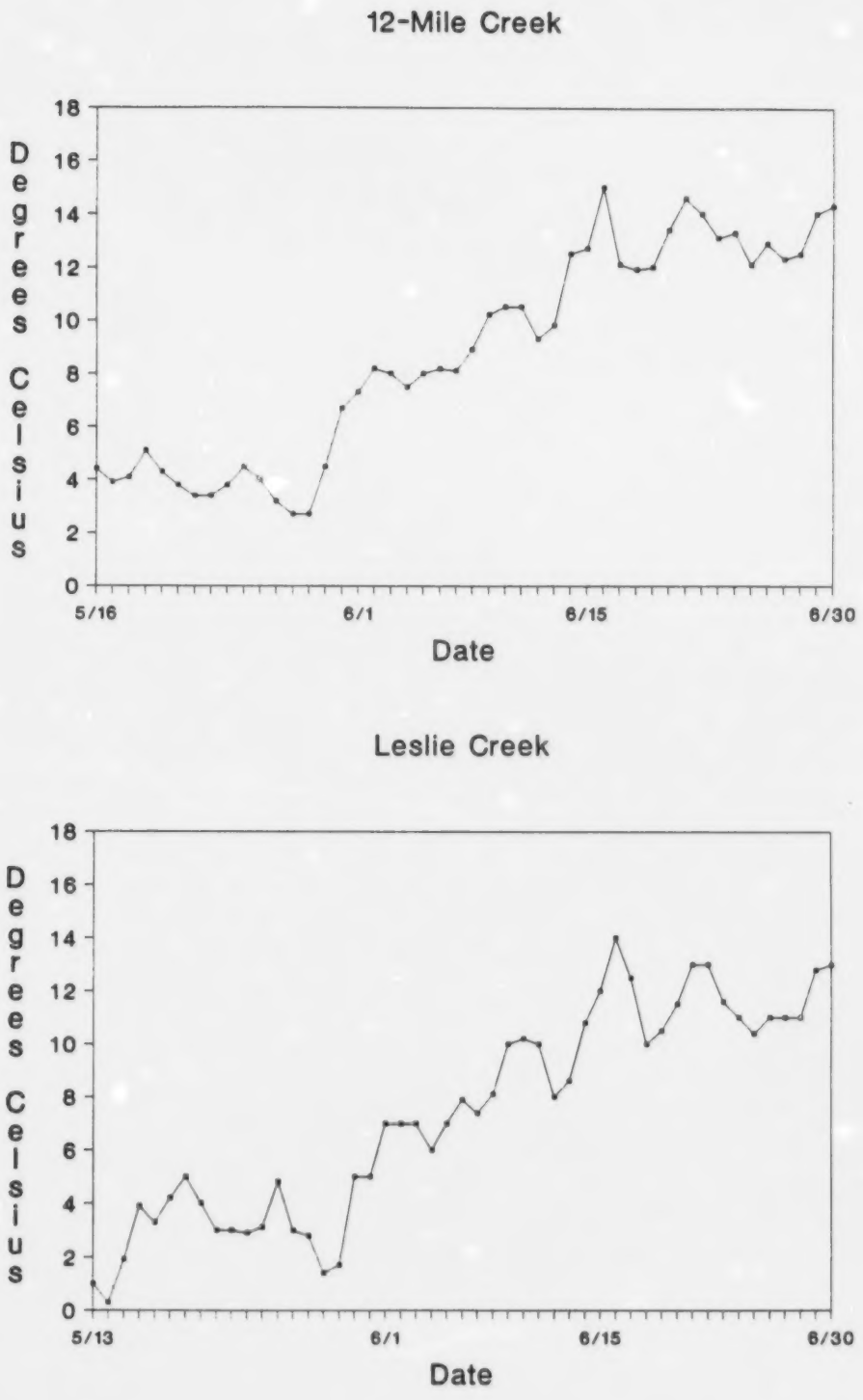
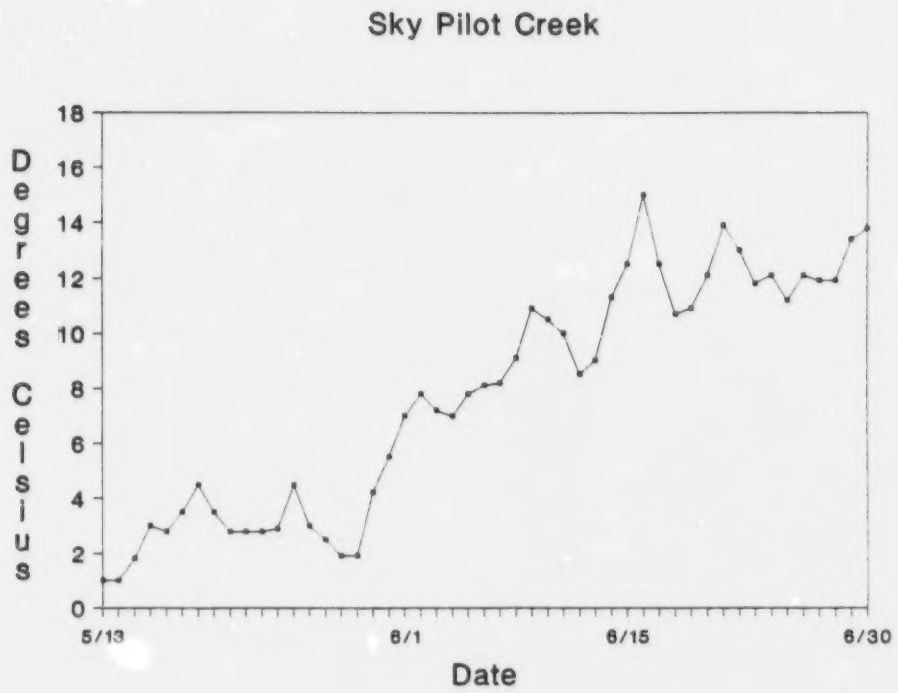


Figure 16. Daily records of temperature in 12-Mile and Leslie creeks during the drift sampling periods, 1989.



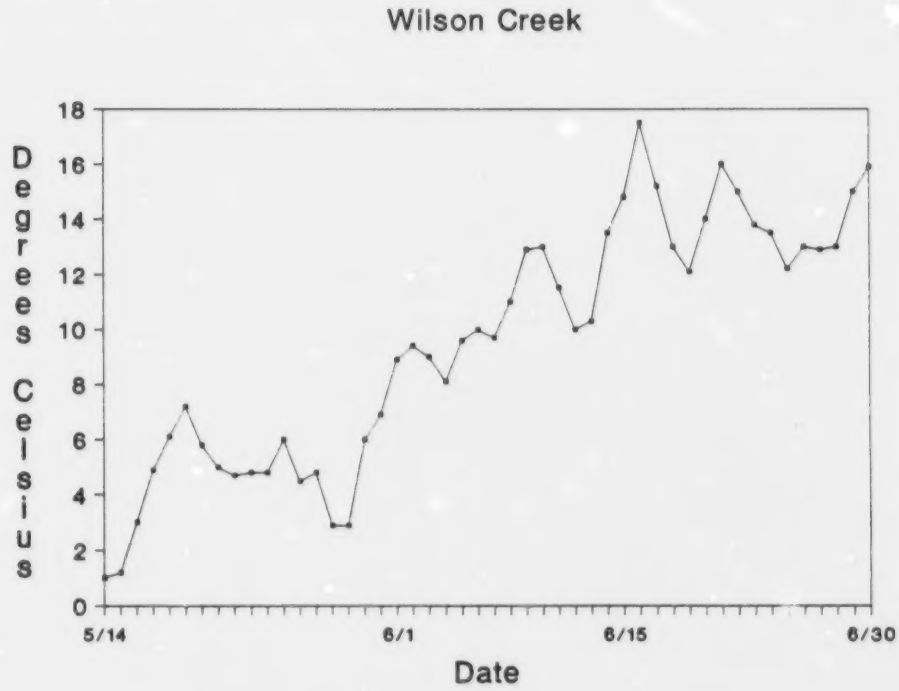


Fig. 17. Daily records of temperature in Sky Pilot and Wilson creeks during the drift sampling periods, 1989.

of the stream (Swanson et al. 1990). This estimate is dependent on the assumption that larvae are distributed randomly within flow (m^3/s) in all areas of the stream. If this assumption is correct, numbers of larvae captured per cubic metre of water per day in traps at various locations should be equal. It is apparent from the daily records of CPUE in the floating trap near the centre of 9-Mile Creek, and the stationary traps near shore, that the assumption is incorrect (Figure 10). Results of a paired t-test on the floating and stationary traps indicate that CPUE is not equal ($p=0.043$).

Daily CPUE in drift traps in Sky Pilot and Wilson creeks are inconclusive. Floating traps collected only one larva in Wilson Creek, and two larvae in Sky Pilot Creek, while none were collected in stationary traps along shore. It is likely that the high discharge in these two streams rendered the drift traps at all locations inefficient.

Total drift would be more accurately estimated by dividing the stream width into several sections with similar flow, and placing a drift trap at the centre of each. Within each section, drift could be estimated from discharge and CPUE in the drift trap located at the centre. Drift in all sections could then be summed to estimate total daily drift in the entire stream.

Spawning Population

For each stream, numbers of brook trout captured daily in fish fences are presented according to direction of travel (Figures 18 and 19). These data do not represent the entire spawning

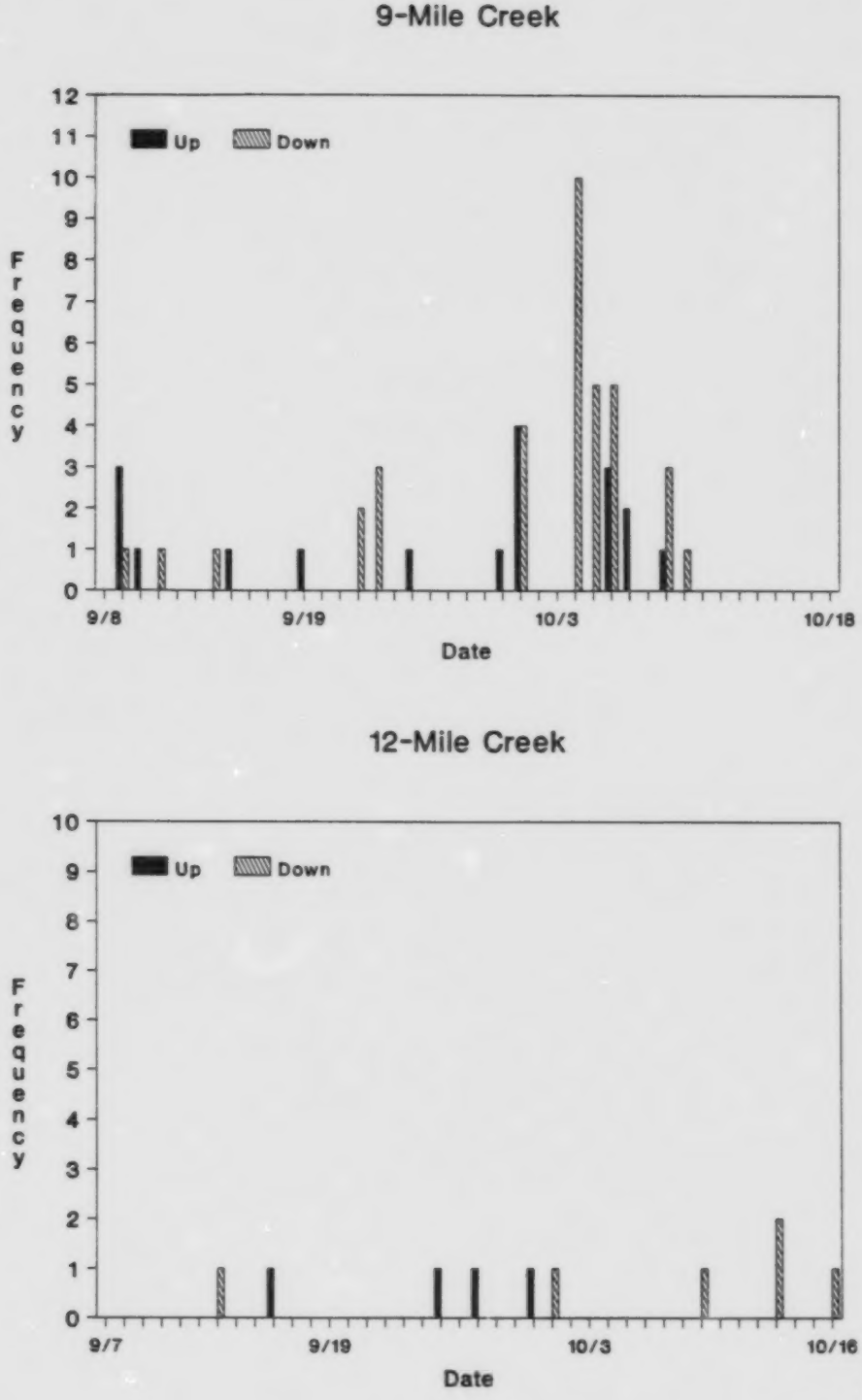


Fig. 18. Numbers of brook trout captured daily in two-directional fish fences in 9-Mile and 12-Mile creeks, fall, 1989.

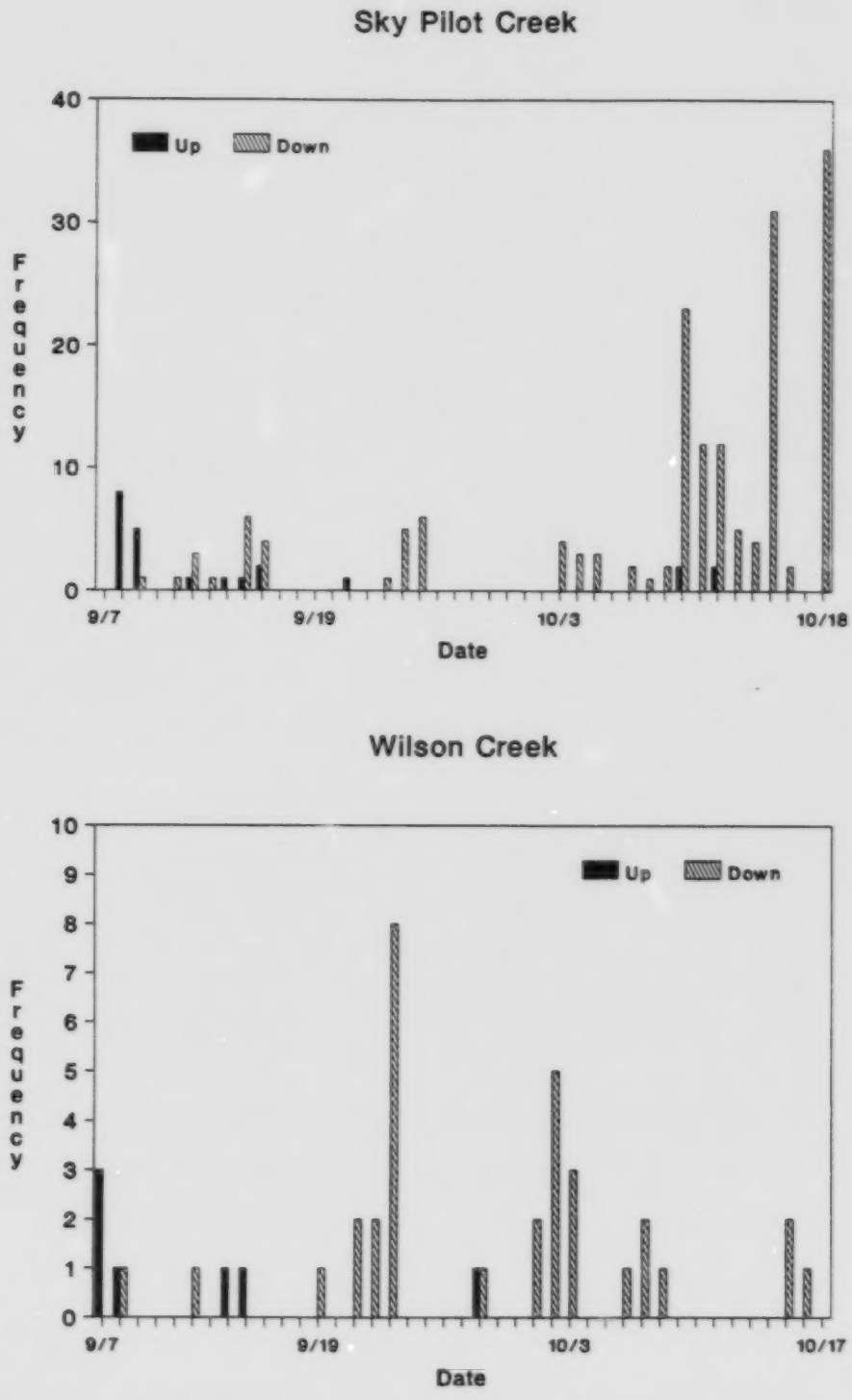


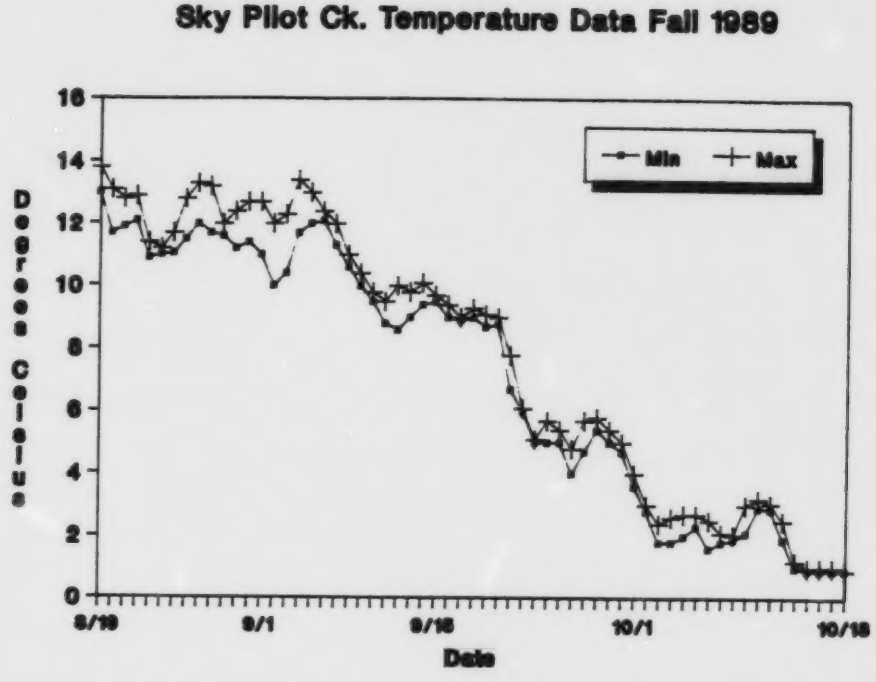
Fig. 19. Numbers of brook trout captured daily in two-directional fish fences in Sky Pilot and Wilson creeks, fall, 1989.

population, but serve to indicate relative levels of trout abundance during hydroelectric development. As in previous years, numbers of trout travelling downstream increased as temperatures decreased (Figures 20 and 21). Daily weights of trout moving upstream and downstream in the fences are presented in Figures 22 and 23.

The numbers and weight of adult trout moving downstream through fall fences in 9-Mile Creek have remained quite stable from 1987 to 1989 (Figure 24, Table 4). The 1989 count was slightly lower than in the previous years, and the total weight decreased quite notably from 1988. The age structure in this stream has shifted to include a much larger percentage of two-year-old individuals and smaller percentages of three- and four-year-old individuals than in 1988 (Figure 25). The increased percentage of younger smaller trout would account for the noticable decrease in overall weight of fish captured between 1988 and 1989.

In 12-Mile Creek, the numbers of trout moving downstream through fall fences have been low in all three years of sampling, and changes in total weight of trout have been proportional to changes in number (Figure 24). Age structures of the samples from 12-Mile Creek over the past three years illustrate one strong year class (three-years old in 1987) which has contributed noticably each year (Figure 26). This strong year class is not as evident in the breakdown of length-frequency since it is represented in more than one length interval in each year (Figure 26).

The number of brook trout moving downstream through fall fences in Wilson Creek decreased slightly between 1988 and 1989



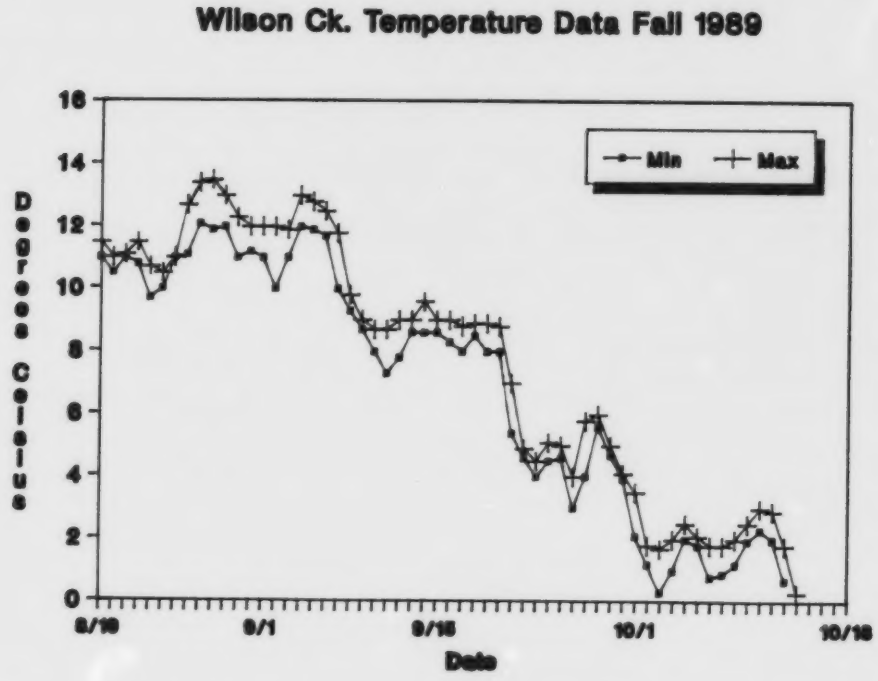
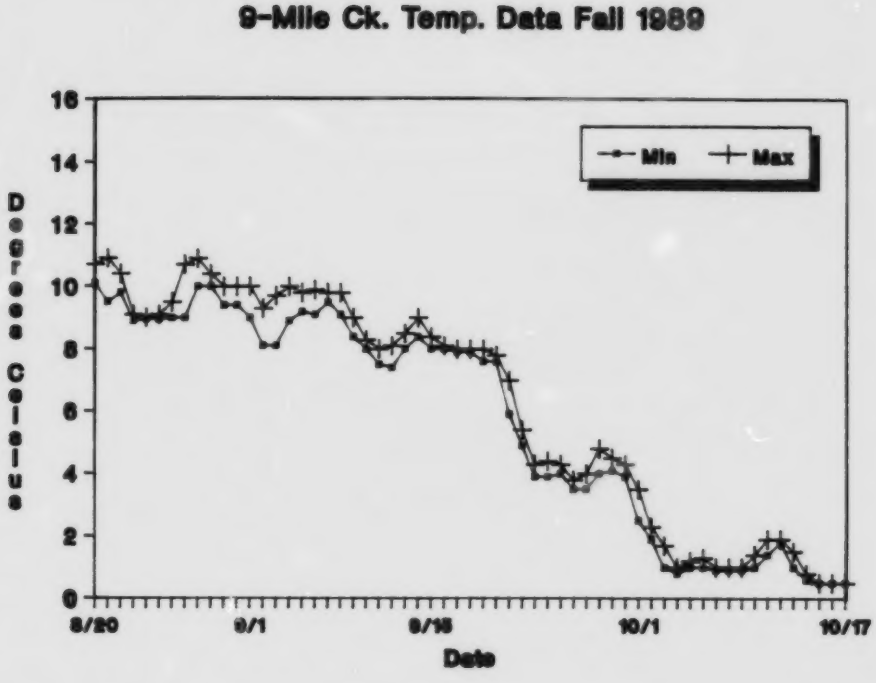


Fig. 20. Daily minimum and maximum water temperatures in Sky Pilot and Wilson creeks during fall, 1989.



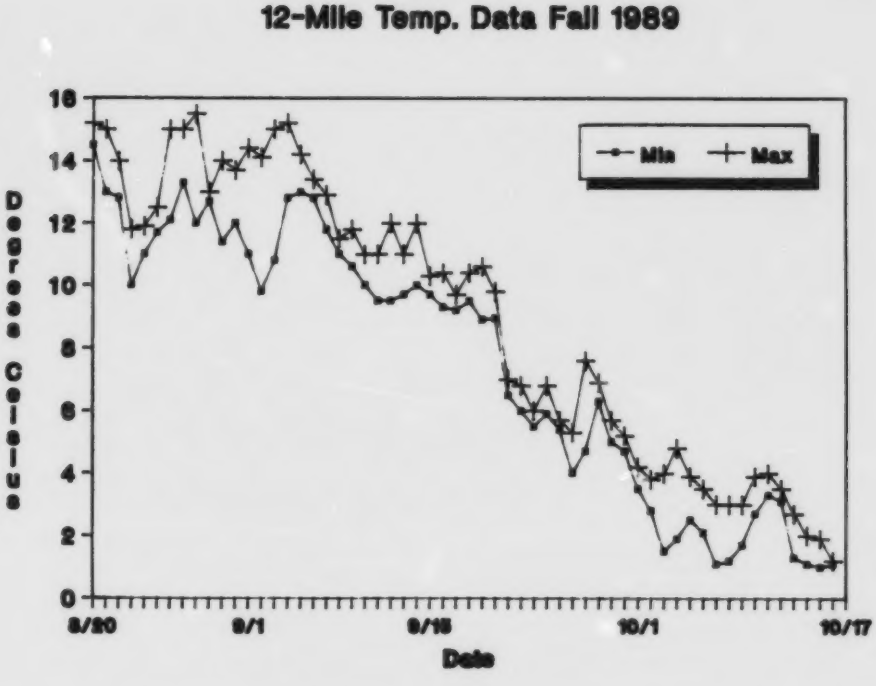


Fig. 21. Daily minimum and maximum water temperatures in 9-Mile and 12-Mile creeks during fall, 1989.

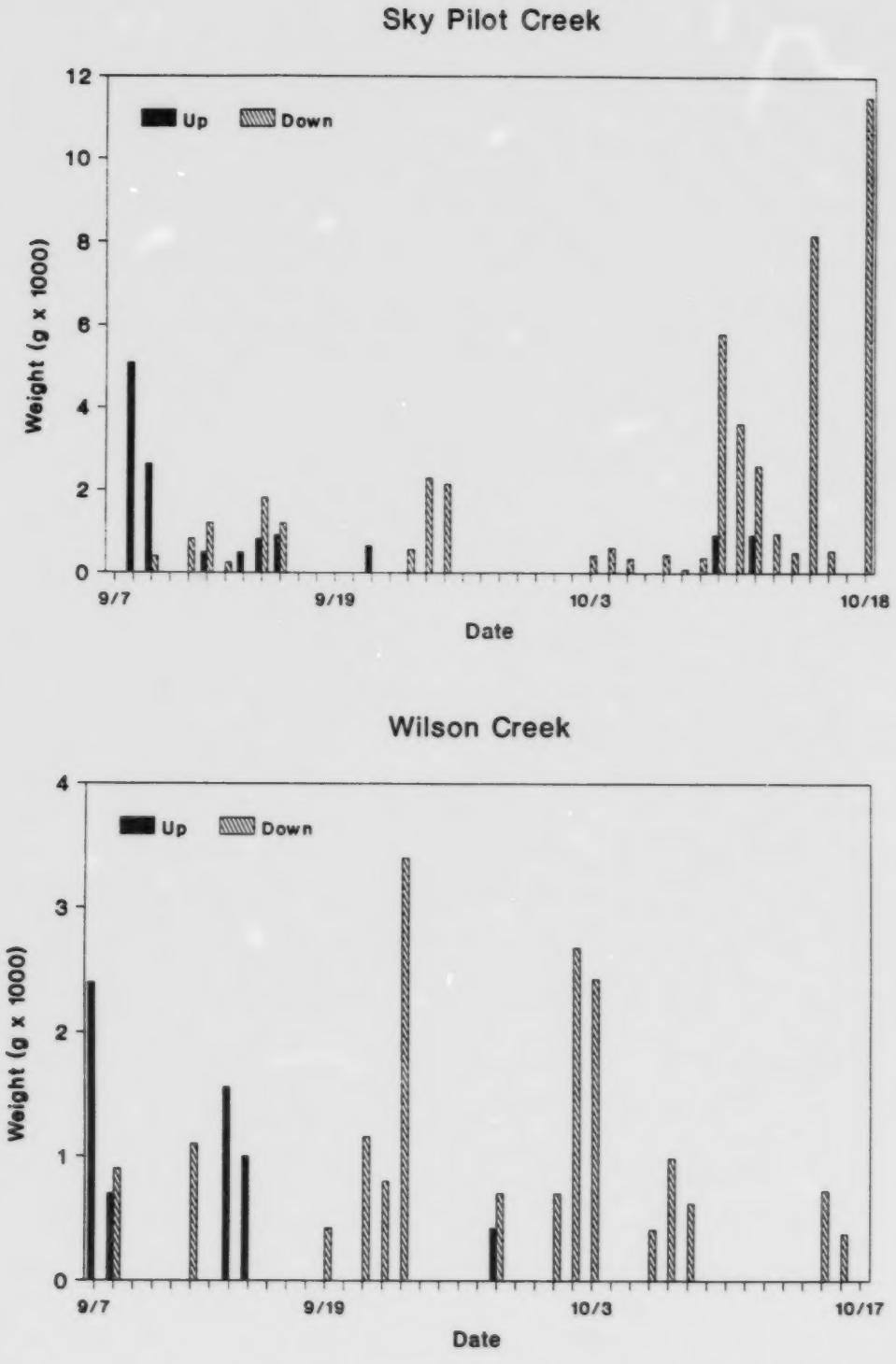


Fig. 22. Weight of brook trout captured daily in two-directional fish fences in Sky Pilot and Wilson creeks, fall, 1989.

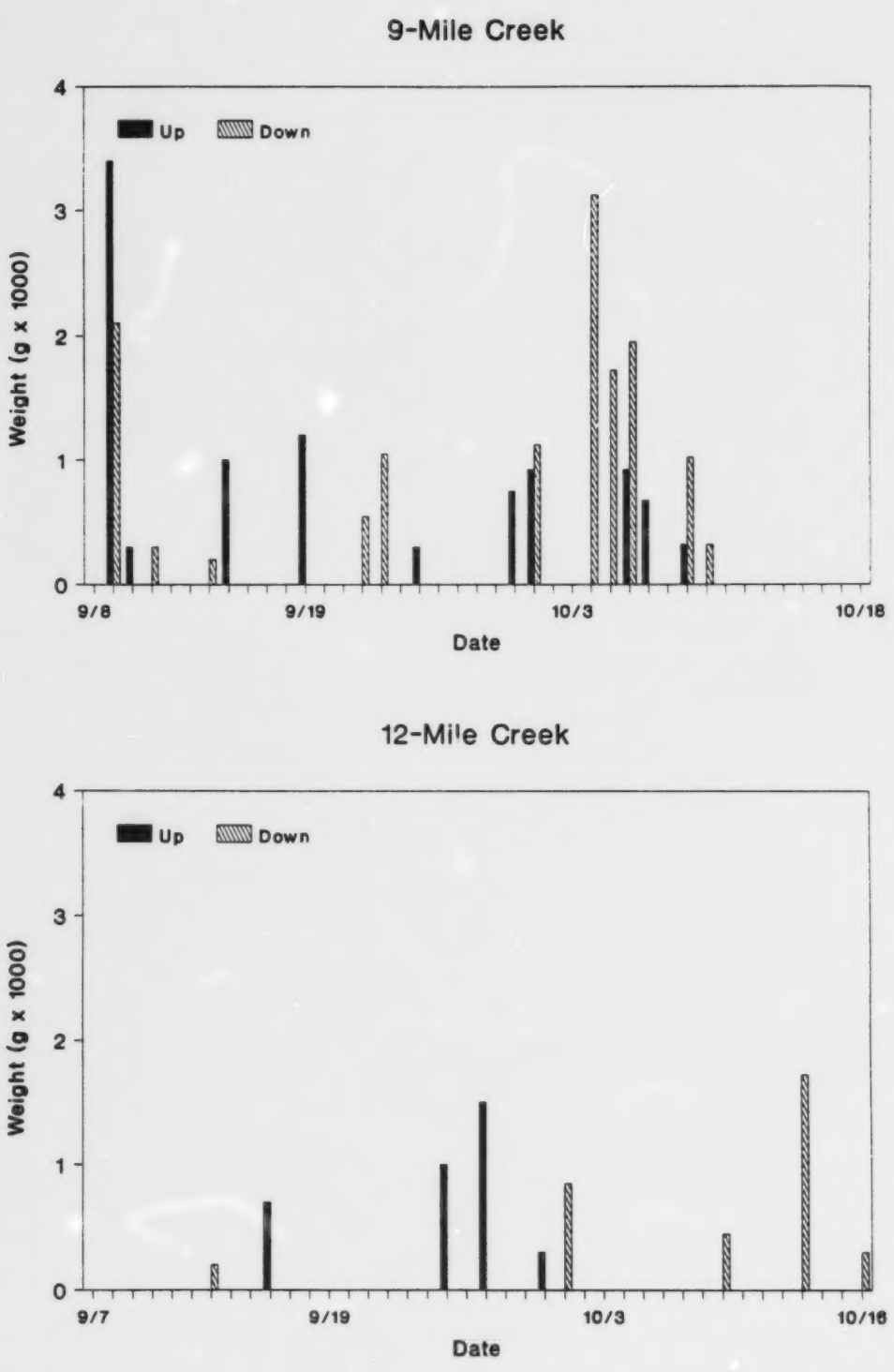


Fig. 23. Weight of brook trout captured daily in two-directional fish fences in 9-Mile and 12-Mile creeks, fall, 1989.

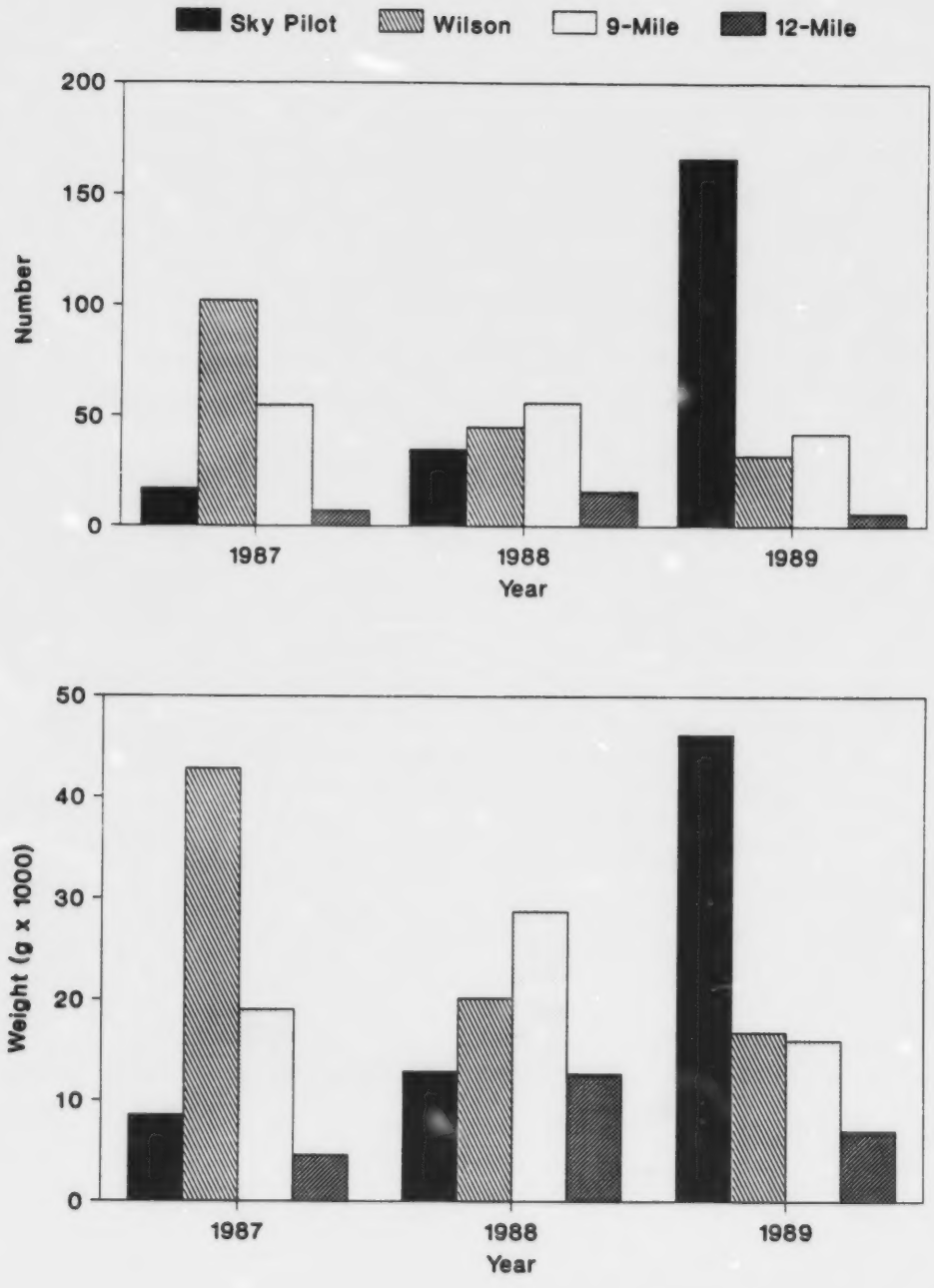


Fig. 24. Frequency and weight of brook trout moving downstream through fall fish fences in Sky Pilot, Wilson, 9-Mile and 12-Mile creeks, 1987-1989.

Table 4. Trout frequencies and weights sampled in upstream and downstream traps during the September - October periods of 1987-89.

Creek	1987				1988				1989			
	Frequency		Weight (g)		Frequency		Weight (g)		Frequency		Weight (g)	
	up	down	up	down	up	down	up	down	up	down	up	down
Sky Pilot	7	17	4230	8570	6	35	1720	12870	23	166	12955	46160
Wilson	1	102	1600	42795	2	45	1275	20175	7	32	6085	16755
9-Mile	30	55	6540	19020	1	56	700	28735	18	42	9800	15950
12-Mile	4	7	2861	4585	2	16	520	12670	4	6	3500	7025
Leslie	--	--	--	--	19	10	13760	4255	--	--	--	--

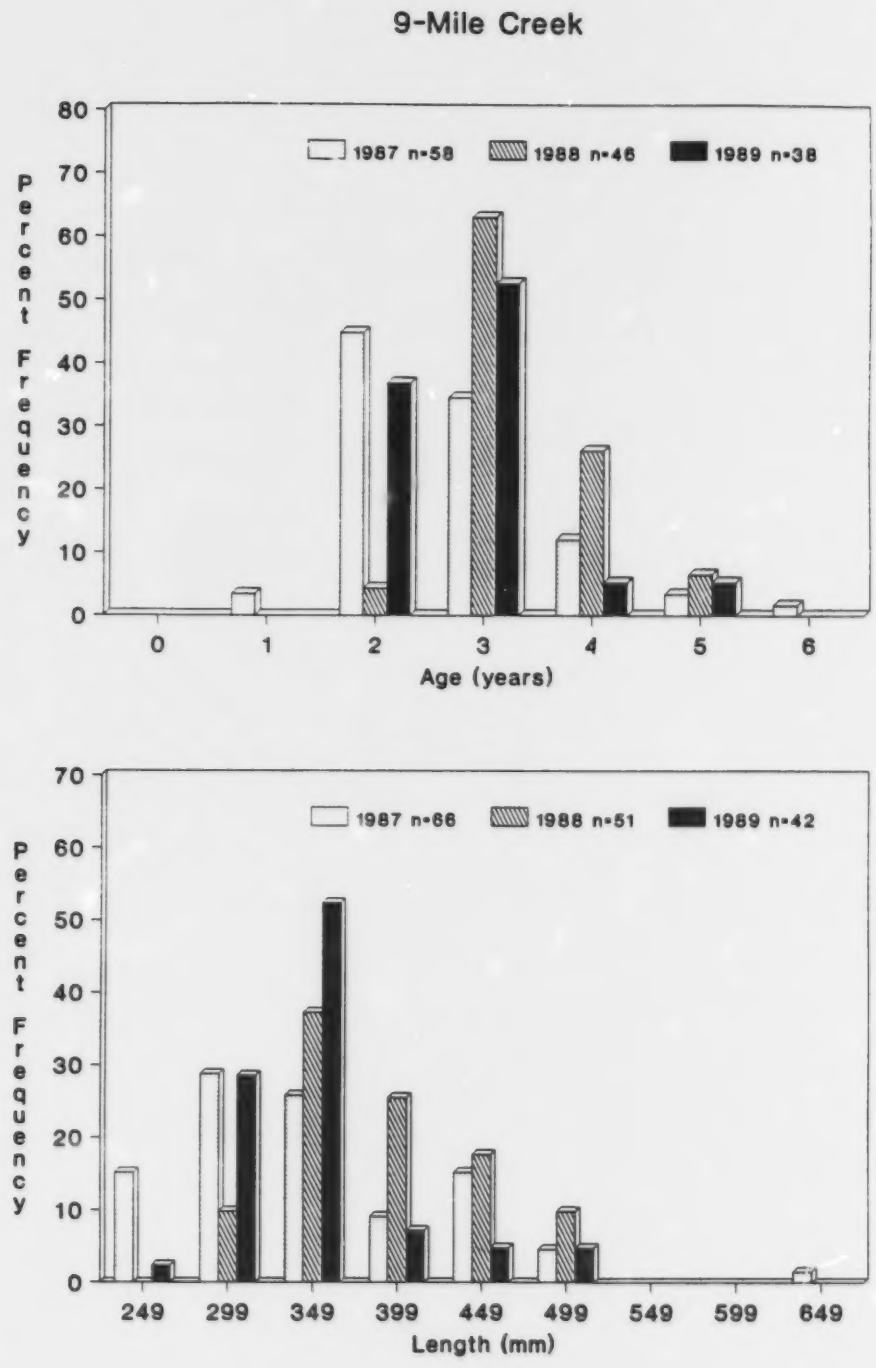


Fig. 25. Age- and length-frequency distributions for brook trout sampled in 9-Mile Creek fish fences in 1987-1989.

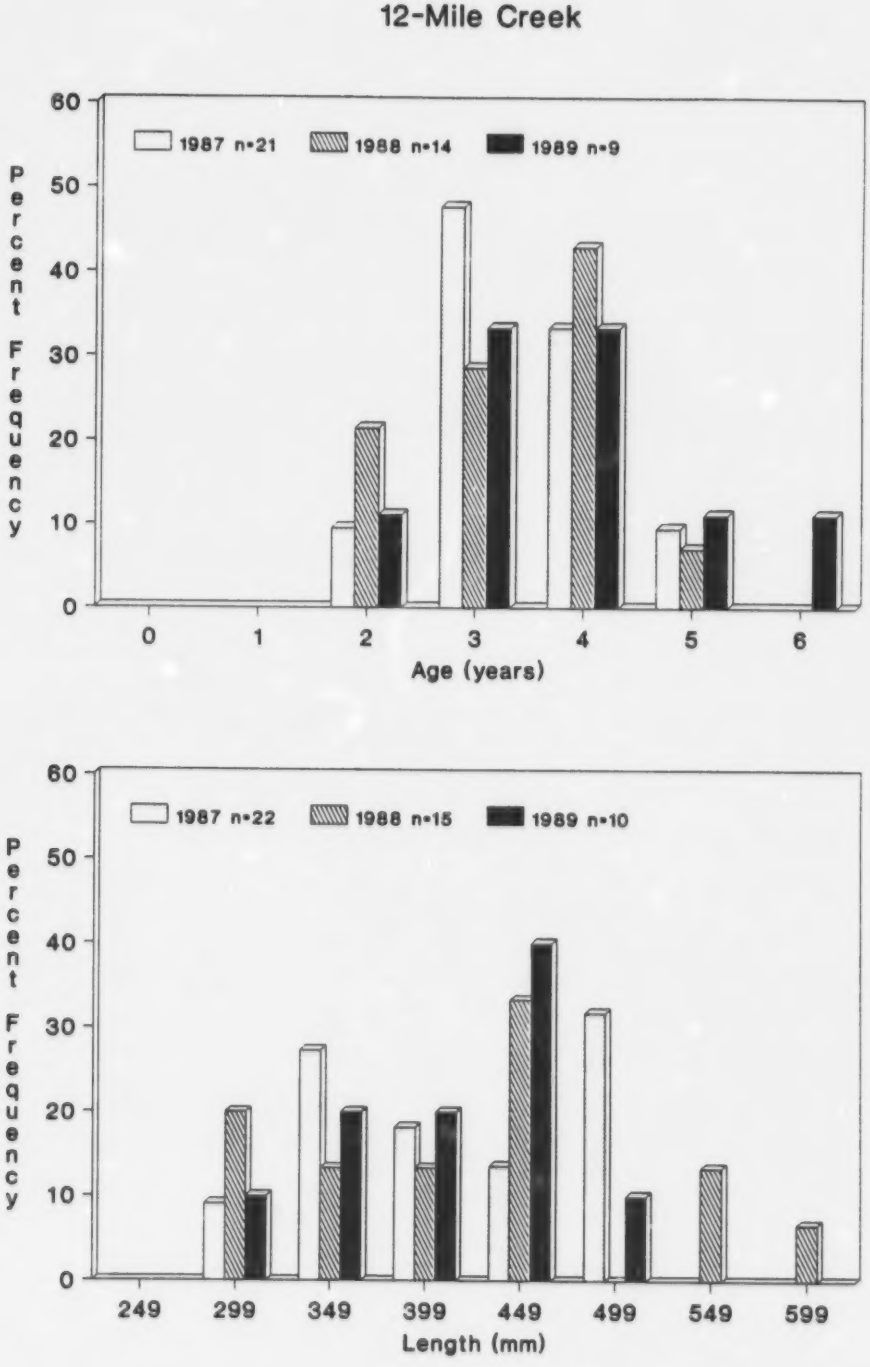


Fig. 26. Age- and length-frequency distributions for brook trout sampled in 12-Mile Creek fish fences in 1987-1989.

(Figure 24). The previous 50% decrease, between 1987 and 1988, is believed to have been the result of high angler harvest of four-year-old trout at the mouth of Wilson Creek in 1988 (Swanson et al. 1990). The age structures of samples illustrate a large cohort of three-year-old trout in 1987 which was not seen again as four-year-old trout in 1988 (Figure 27). High angling pressure on Wilson Creek continued between 1988 and 1989, and the age structure in 1989 remained similar to that of 1988.

The number of trout moving downstream through fall fences in Sky Pilot Creek increased over four times between 1988 and 1989 (Figure 24). The reasons for this increase are unknown, but may relate to changes in upstream habitat or differences in temperature decline between years. A large number of trout were captured moving downstream on the final day of sampling in 1989 (Figure 19), following four days of constant low water temperatures (1°C) (Figure 20). Perhaps such a prolonged period of near-freezing temperature is necessary to trigger downstream movement of some fish, and did not occur during fence operation in 1987 and 1988.

Alternatively, the increase in numbers may be related to habitat. Brook trout may have remained in upstream areas of Sky Pilot Creek in 1987 and 1988 if suitable habitat was available, or if passage was impaired. Cunjak (1988) found that brook trout stop and remain in slow deep areas if encountered while drifting downstream in fall. Such habitat is available upstream of numerous beaver dams in Sky Pilot Creek. However, if one or more of these dams was altered or destroyed the numbers of trout travelling downstream to the fences might increase, as in 1989.

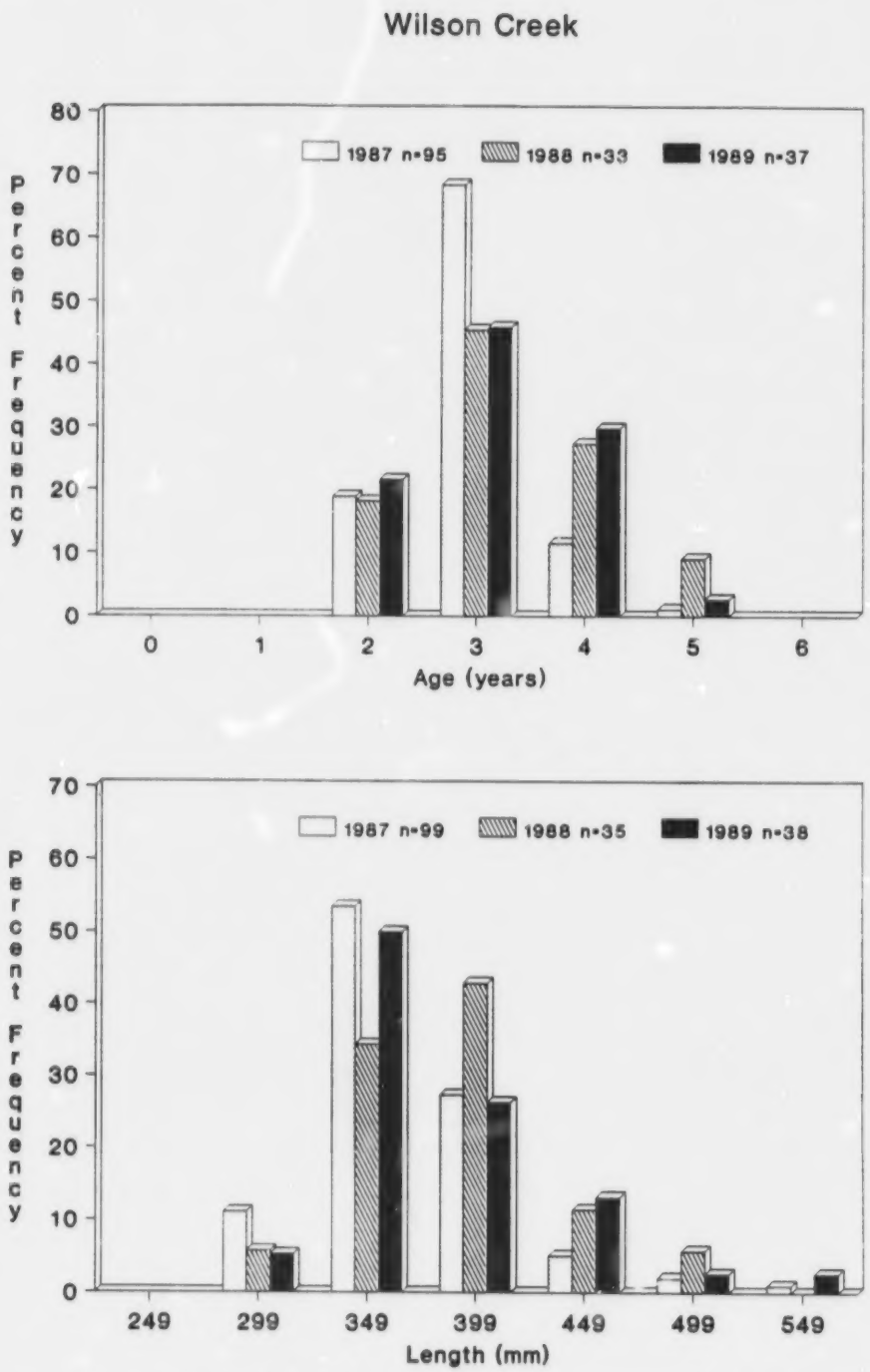


Fig. 27. Age- and length-frequency distributions for brook trout sampled in Wilson Creek fish fences in 1987-1989.

The increase in numbers in 1989 can not be attributed to the introduction of a strong new age group, since the age structure of samples from the past three years has remained quite stable (Figure 28). This age structure, which takes a sharp decline at four years of age, reflects the high angling pressure that this easily accessible stream receives. The length-frequency distributions of samples from Sky Pilot Creek also reflect high angling harvest since 1987, as there are few fish longer than 350 mm (Figure 28).

Floy Tagging

Three hundred and seventy one brook trout were tagged during studies of the lower Nelson River system in 1989. Table 5 presents a record of the numbers of trout tagged in each stream, by year, and over all years. Table 6 presents a summary of recaptures in 1989, including brook trout tagged in 1989, and those tagged previous to 1989. The tagging history of each recaptured brook trout is presented in Appendix 1.

Table 7 presents a summary of trout recaptured in each study stream, as a percentage of the total number tagged in the stream of origin. Data are for the years from 1985 to 1989. Recaptures were included only if a significant move had occurred, e.g from one stream to another, or, in the case of a fish recaptured in the same stream as it was tagged, only if a sufficient period of time had elapsed since release to allow dispersal. If a fish was captured while travelling upstream to spawn and again while travelling downstream following spawning the recapture was not included in

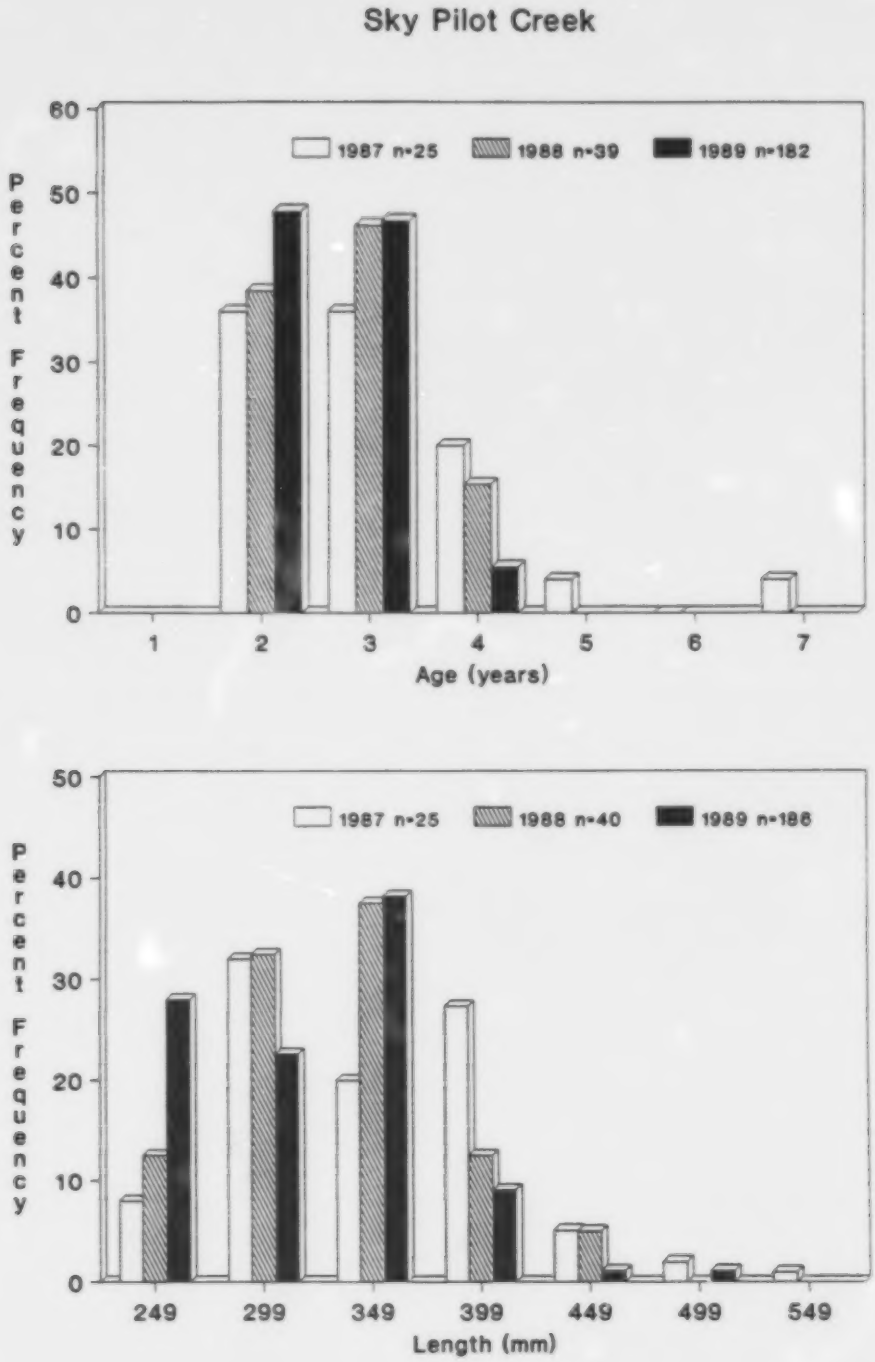


Fig. 28. Age- and length-frequency distributions for brook trout sampled in Sky Pilot Creek fish fences in 1987-1989.

Table 5. Number of brook trout tagged in study streams each year.

Stream	1985	1986	1987	1988	1989	Total
Limestone R.	29	14	7	17	14	81
9-Mile Ck.	28	4	59	51	53	195
12-Mile Ck.	5	0	21	16	6	48
CN Ck.	2	0	71	16	20	109
Bird Ck.	2	0	0	0	0	2
Sky Pilot Ck.	83	0	25	39	194	341
Wilson Ck.	7	0	99	34	37	177
Leslie Ck.	0	1	0	28	3	32
Moondance Ck.	41	1	61	8	18	132
Sundance Ck.	2	0	0	0	0	2
Beaver Ck.	0	0	2	0	0	2
Swift Ck.	4	0	0	0	0	4
Weir R.	0	35	0	23	0	58
French Ck.	0	0	0	6	25	31
McMillan Ck.	0	0	0	2	0	2
God's R.	0	0	0	27	0	27
Goose Ck.	0	0	0	0	1	1
Nelson R.	0	0	0	0	0	0
Total	203	58	345	267	371	1244

Table 6. Summary of new brook trout tags in 1989, recaptures of 1989 tags and recaptures of tags from previous years (1985-88) in 1989.

Stream	New Tags	1989 Tags Recaptured	1985-1988 Tags Recaptured	Known Tag Losses
Limestone R.	14	5	2	1
9-Mile Ck.	53	14	7	2
12-Mile Ck.	6	0	3	0
CN Ck.	20	3	2	3
Bird Ck.	0	0	0	0
Sky Pilot Ck.	194	4	1	2
Wilson Ck.	37	6	1	5
Leslie Ck.	3	0	0	0
Moondance Ck.	18	1	0	1
Sundance Ck.	0	0	0	0
Beaver Ck.	0	0	0	0
Swift Ck.	0	0	0	0
Weir R.	0	0	0	0
French Ck.	25	0	0	0
McMillan Ck.	0	0	0	0
God's R.	0	0	0	0
Goose Ck.	1	0	0	0
Nelson R.	0	0	0	0
Total	371	33	16	14

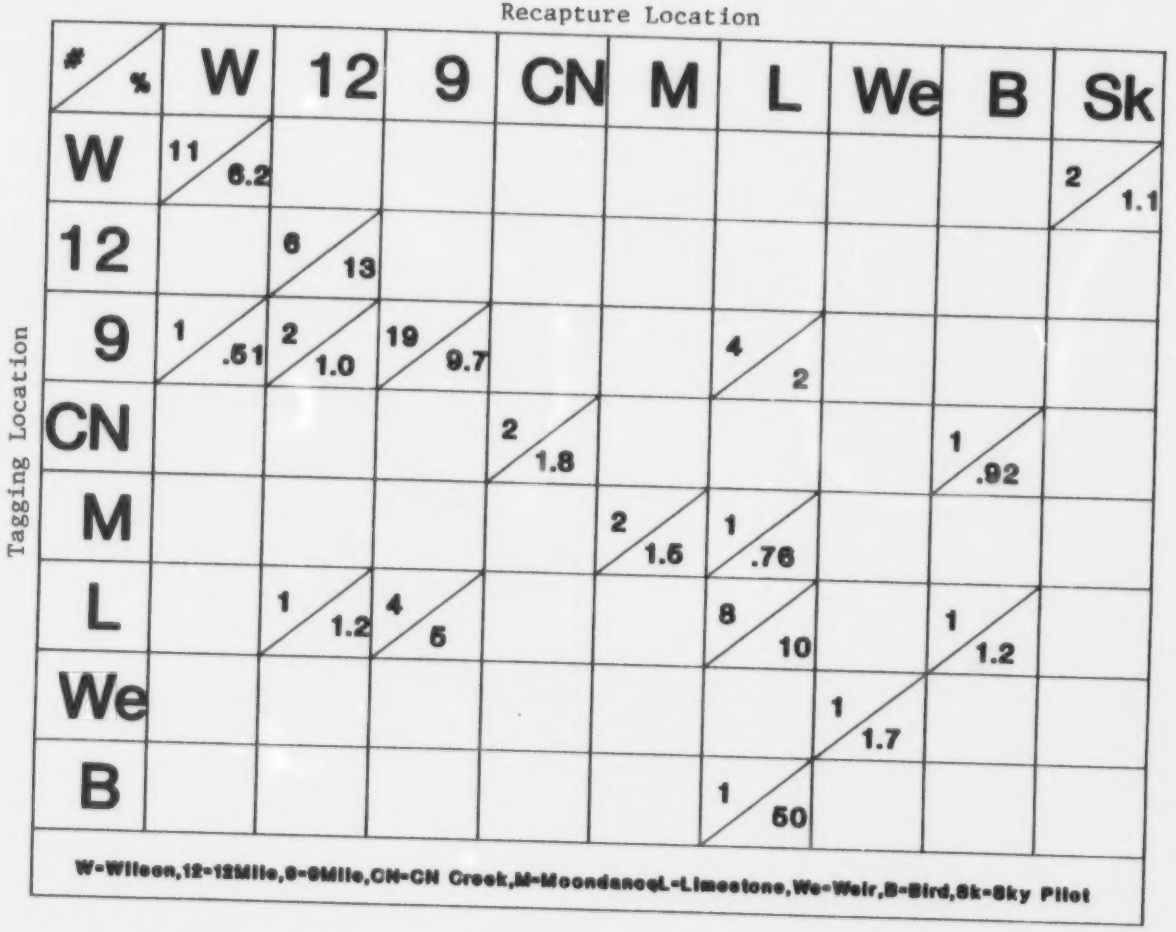


Table 7. Summary of trout recaptured in each study stream as a percentage of total tagged in stream of origin, 1985-1989.

this analysis. The results indicate that as expected the greatest percentages of recaptures occurred in the same streams where the fish had been tagged. The next highest percentages occurred in streams near those where the fish were tagged. Recaptures of fish tagged in the Limestone River were common in its tributaries and vice versa. A few recaptures occurred in streams far from those where the fish were tagged. Brook trout in the Nelson River system appear to use tributaries opportunistically, providing potential for mixing of stocks.

Strontium Analysis

The level of anadromy (fish having spent part of their life in marine conditions) among brook trout captured during monitoring studies in 1989 was estimated as 0.84% (3 of 359 fish). This level is consistent with that found in recent years. Streams included in this analysis were the Limestone River, Leslie, Goose, 12-Mile, CN, Moondance, Wilson, 9-Mile and Sky Pilot creeks.

The level of anadromy was also determined for a sample of brook trout from French Creek, which discharges into the estuary of the God's River. These trout were collected for enhancement of the Kettle River stocks, as described elsewhere in this report. Eighteen of twenty six trout, 69.23%, were classified as anadromous. These data support the previous finding that the level of anadromy for brook trout in streams increases with proximity to Hudson Bay (Swanson and Kansas 1987).

CONCLUSIONS

1. As in previous years, juvenile brook trout utilized rearing habitat in both spawning streams and smaller nursery-only streams in the Conawapa Forebay. Spawning streams continue to harbour greater numbers of juveniles, likely those which hatched in the stream, while nursery streams provide habitat for those which have drifted out of spawning streams to the Nelson River, and then migrated into nursery streams.

2. The population of brook trout rearing in CN Creek in 1989 was again (as in 1988) half as large as in 1987. Once more, freezing and washing out of the road crossing, due to problems with culvert operation, was responsible for the small population. The rush of water when the crossing washed out would have flushed many trout out to the Limestone River, and deposited large amounts of sediment thereby decreasing suitable habitat and benthic food production.

3. Efficiency of drift samplers for larval brook trout is influenced by discharge and location in a stream. In small streams such as CN, Leslie and 9-Mile creeks substantial numbers of larvae are captured each year because a large percentage of the flow is sampled. Few, if any, larvae are collected in larger streams such as

12-Mile or Sky Pilot creeks where traps sample only a small percentage of the high discharge.

4. Larval brook trout drift appears closely related to spring water temperatures. When water temperature dropped to less than 2°C larvae were no longer captured; once temperature increased, larvae were again found in drift samples.

5. Comparison of catch per unit effort (CPUE) in drift traps located in fast verses slow flow indicated that larval drift is not random across the streams. It is therefore not accurate to estimate total drift from CPUE at only one location in a stream cross section.

6. Numbers of adult brook trout captured in fish fences following spawning were similar to previous years, in 9-Mile and 12-Mile creeks. The number captured in Wilson Creek was slightly lower than in 1988, as angling pressure continued to be high. In Sky Pilot Creek the number increased to four times that of 1988. This does not necessarily indicate a population increase, but instead may reflect a change in habitat conditions resulting in greater movement downstream than in previous years.

7. Floy tag recaptures continue to illustrate opportunistic

use of habitat by brook trout in the Nelson River system. There is potential for mixing of stocks between streams.

8. Less than one percent of brook trout sampled for strontium analysis during monitoring studies had spent part of their life in the sea. In comparison, 69% of brook trout sampled from French Creek near Hudson Bay were anadromous. As determined in previous studies, the level of anadromy increases with proximity to Hudson Bay.

RECOMMENDATIONS

1. Once more the impacts of road crossing washout on CN Creek have indicated the importance of consideration for fish habitat during maintenance as well as planning and construction of developments. Stream crossings which require special operation or maintenance, such as heating cables, should be inspected regularly.

2. Drift of larval brook trout does not appear to be random across the width of a stream. Therefore, total daily drift of larval brook trout should be estimated by dividing the stream width into several sections and installing a drift trap at the centre of each section. Drift in each section can be estimated using CPUE and discharge, then summed over all sections to estimate total stream drift.

3. As the number of adult trout captured in Wilson Creek fish fences continues to be low, and angling pressure continues to be high, efforts should be made to ensure that harvest is maintained within the legal limit of one fish per day. Visits to popular angling sites by enforcement officers should be a priority.

PART VII

LAKE STURGEON INVESTIGATIONS

PART VII

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INTRODUCTION

Studies on lake sturgeon in North America have shown that this species reacts negatively to commercial development, exploitation, pollution and habitat loss through hydroelectric development (Thuemler 1985, Auer 1988, Housten 1987). While these influences would impact unfavourably on any fish species, the sturgeon's unique biological characteristics make it particularly susceptible. Recent studies on the impacts of hydroelectric development on sturgeon in the lower Nelson River have come to similar conclusions, although details such as the status of a self propagating population in the system are unclear (Swanson and Kansas 1987; Swanson et al 1990). No sturgeon under ten years of age have been found during the course of these studies therefore efforts to find evidence of recruitment in the Lower Nelson River and its tributaries were warranted.

A number of studies were initiated in 1989 to investigate the apparent gap in the life history of lower Nelson River sturgeon. The studies were as follows: 1) test net below the Long Spruce Generating Station (L.S.G.S.) in spring to determine if sturgeon use the base of the hydro dam to spawn, 2) investigate Angling Lake and Angling River for evidence of sturgeon spawning in these areas, and 3) monitor existing radio tagged sturgeon in Angling Lake to characterize basic use of the system and locate spawning sites (Figure 1).

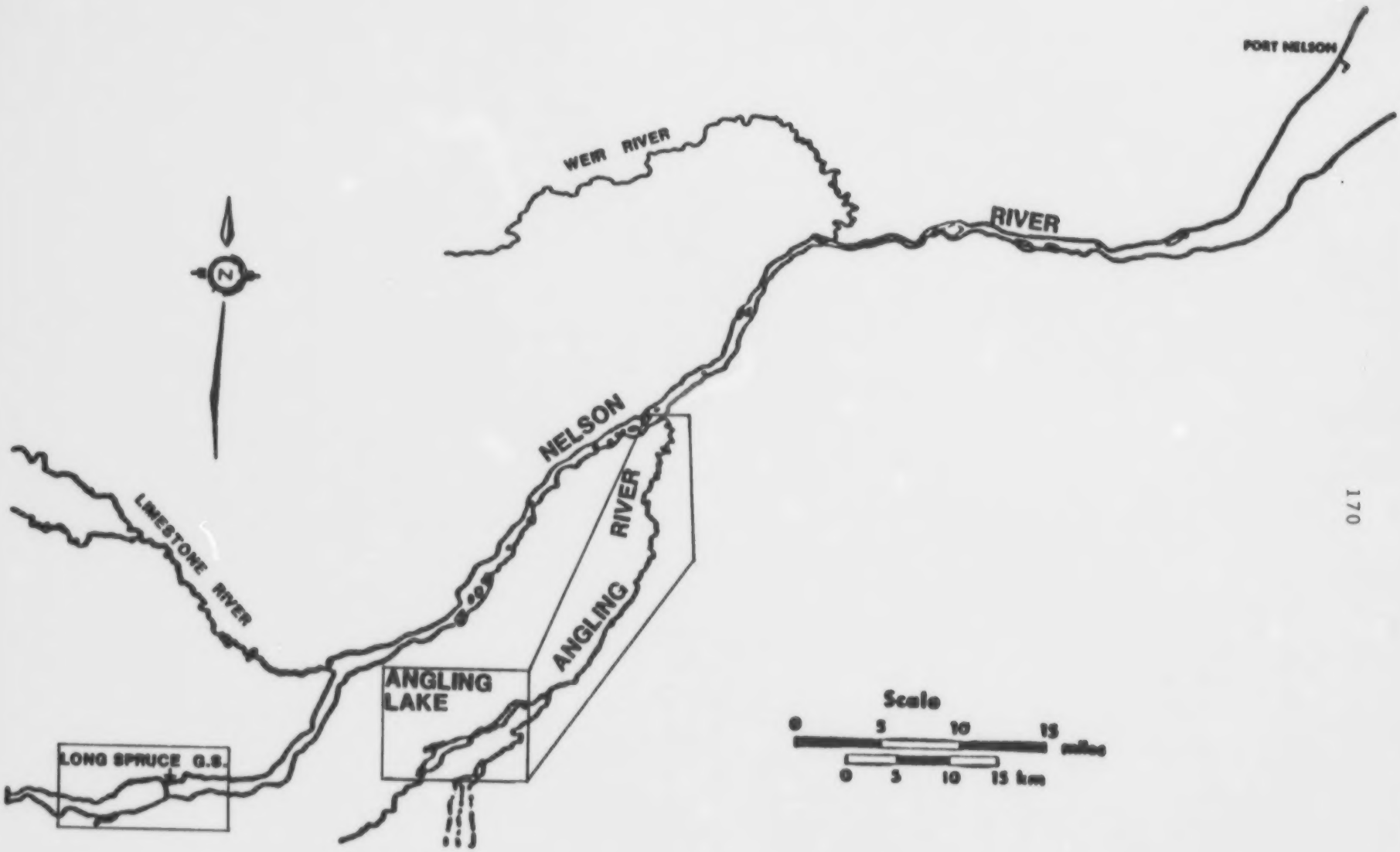

Fig. 1. Study areas for sturgeon in the Lower Nelson River, 1989.

METHODS

L.S.G.S. Spillway Netting

Gill nets were set in the spillway area of the L.S.G.S. immediately after ice break up, June 4-7 and June 14-27, 1989 (Figure 2). The spillway was the only area available to put nets in due to the shelter from current that it provided. No water passed through the spillway during the sampling period therefore the area below remained relatively current free. Nets used had mesh sizes of 22.9 cm and 30.5 cm (stretch measure), and were 25 m to 50 m long and 2.5 m deep. Nets were set in the morning, checked for fish the following morning, then reset no more than an hour after pulling; each net was set for no less than 23 hours.

Temperature readings were taken each day at approximately the same time (between 9:30 a.m. and 10:30 a.m.) with a FLUKE Model 51 electronic thermometer.

Sturgeon captured were sampled for total length, fork length and weight. Pectoral fin rays were removed for age determination as per Wilson (1987). Sturgeon released were examined externally to determine sex and spawning condition, and tagged with a numbered disc tag on the caudal fin. Use of disc tags was discontinued when it was found that recaptured sturgeon were held in the net only by the tag, resulting in damage to the tail. Disc tag use was also discontinued because of the apparent bias it created when sturgeon with tags were more easily captured. Floy spaghetti tags were used in place of the disc tag.

Six sturgeon were sacrificed to assess spawning condition.

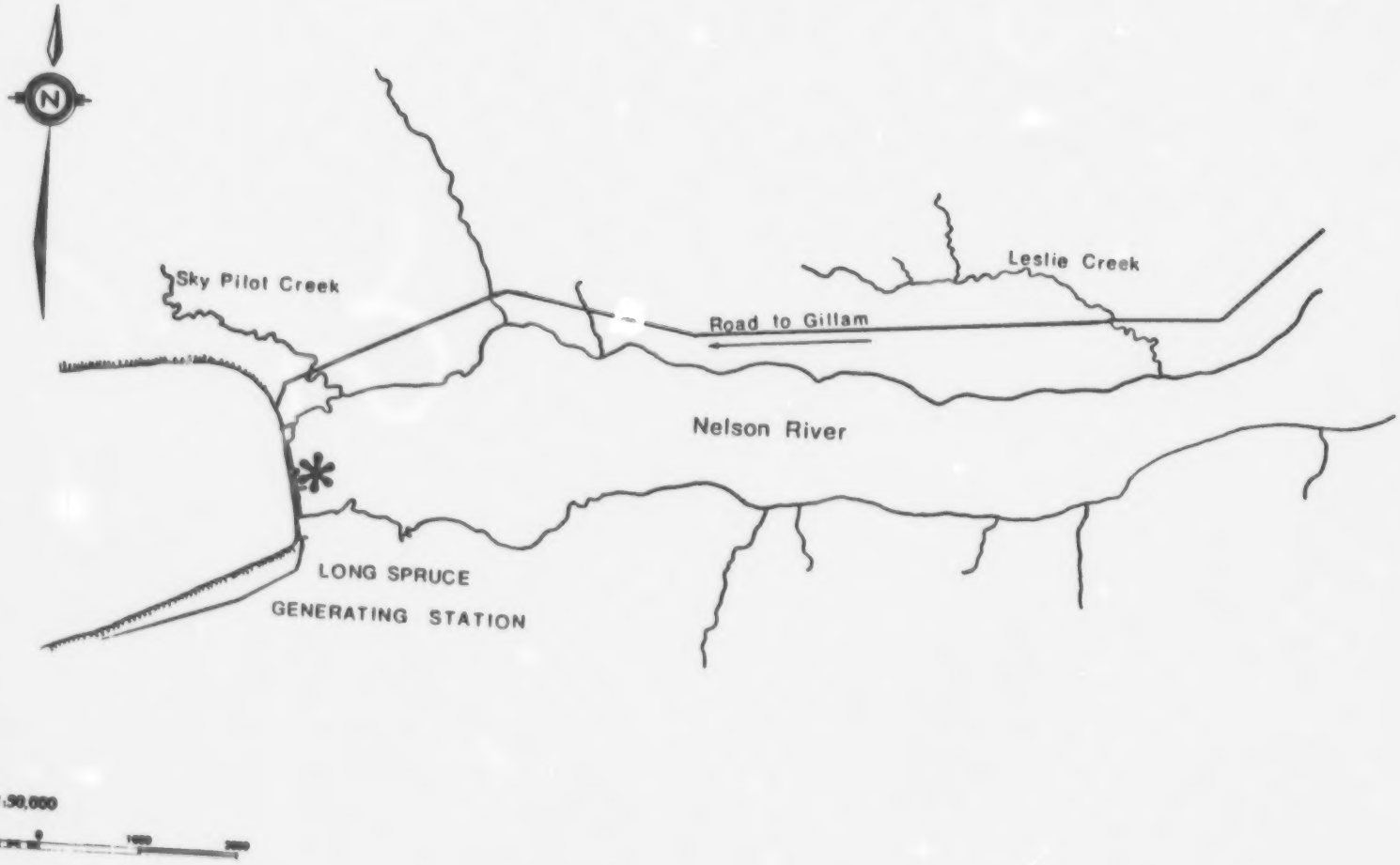

Fig. 2. Location of spillway at the Long Spruce Generating Station and gill net sites in June, 1989.

Samples were donated to Dr. T. Dyck of the University of Manitoba for isozyme and parasite analysis, and Mr. James Brown of Simon Fraser University for mt DNA analysis.

Angling Lake

Angling Lake was sampled for young-of-the-year and juvenile sturgeon from July 6 to 17, 1989. Locations sampled and gear used are presented in Figure 3. A 15 m x 1.5 m beach seine was used along with a Smith-Root Model II-A backpack electrofisher, pop-up traps, light traps and gill nets (5.1 cm mesh size, stretch measure). Additional species captured were counted only.

Concurrent these investigations, three adult sturgeon were collected using larger mesh gill nets. Dr. T. Dyck of the University of Manitoba, used these specimens for isozyme and parasite analysis.

Angling River

The entire length of the Angling River, from the outlet of Angling Lake to the mouth at the Nelson River, was traversed by canoe between August 19 and 25, 1989 (Figure 1). Gill nets, 5.1 cm and 7.6 cm mesh size (stretch measure), and hoop nets were preset by helicopter and lifted as encountered during the canoe trip down the river. All nets were set on August 19, 1989; sites A and B were lifted on August 20 (Figure 4). Site C was lifted on August 21. Sampling was also conducted by means of electrofishing, seining and rotentone (Figure 4). A Smith-Root Model II-A Backpack electrofisher was used to cover most habitat types along

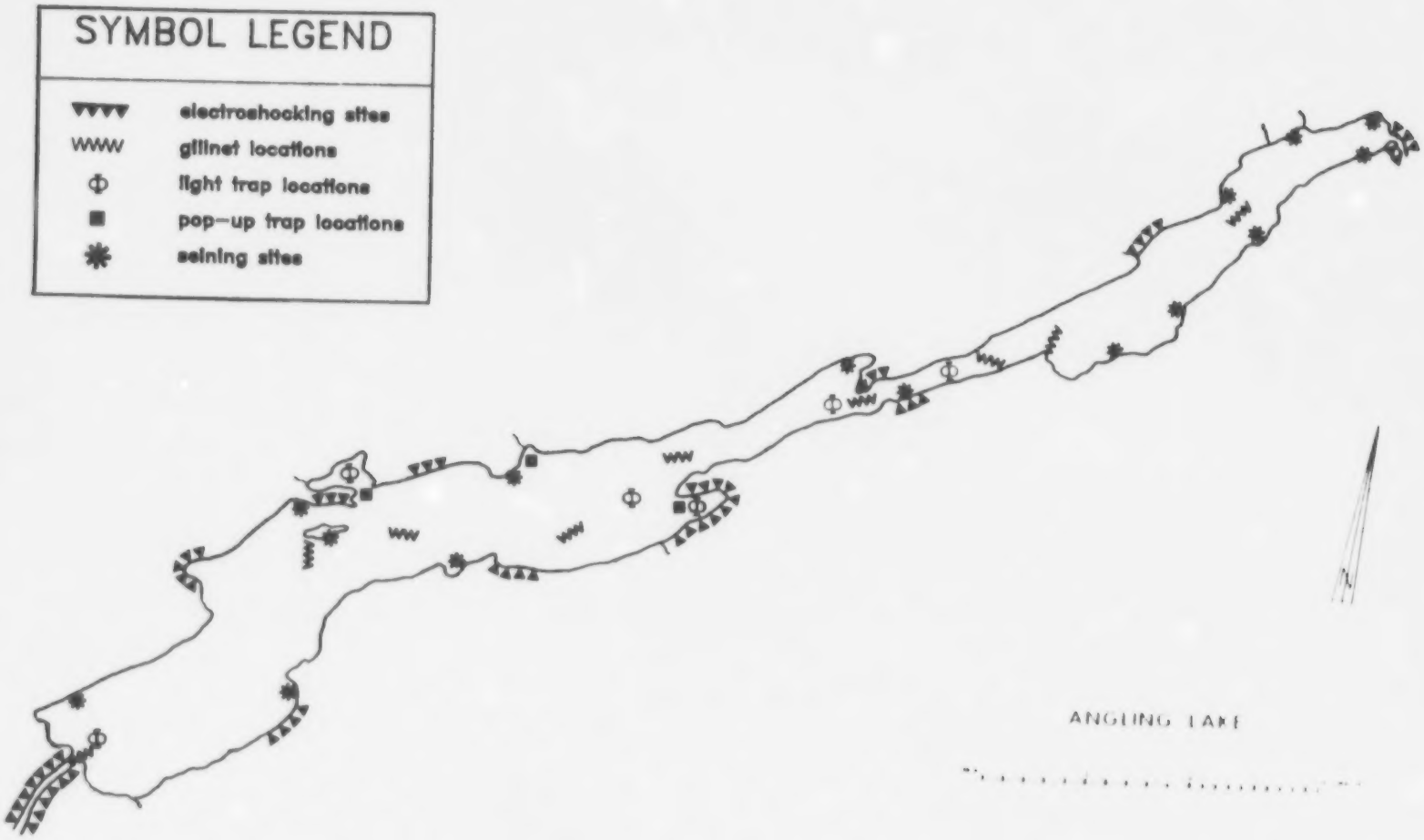

Fig. 3. Locations sampled and gear used in fishing for young-of-the-year and juvenile sturgeon.

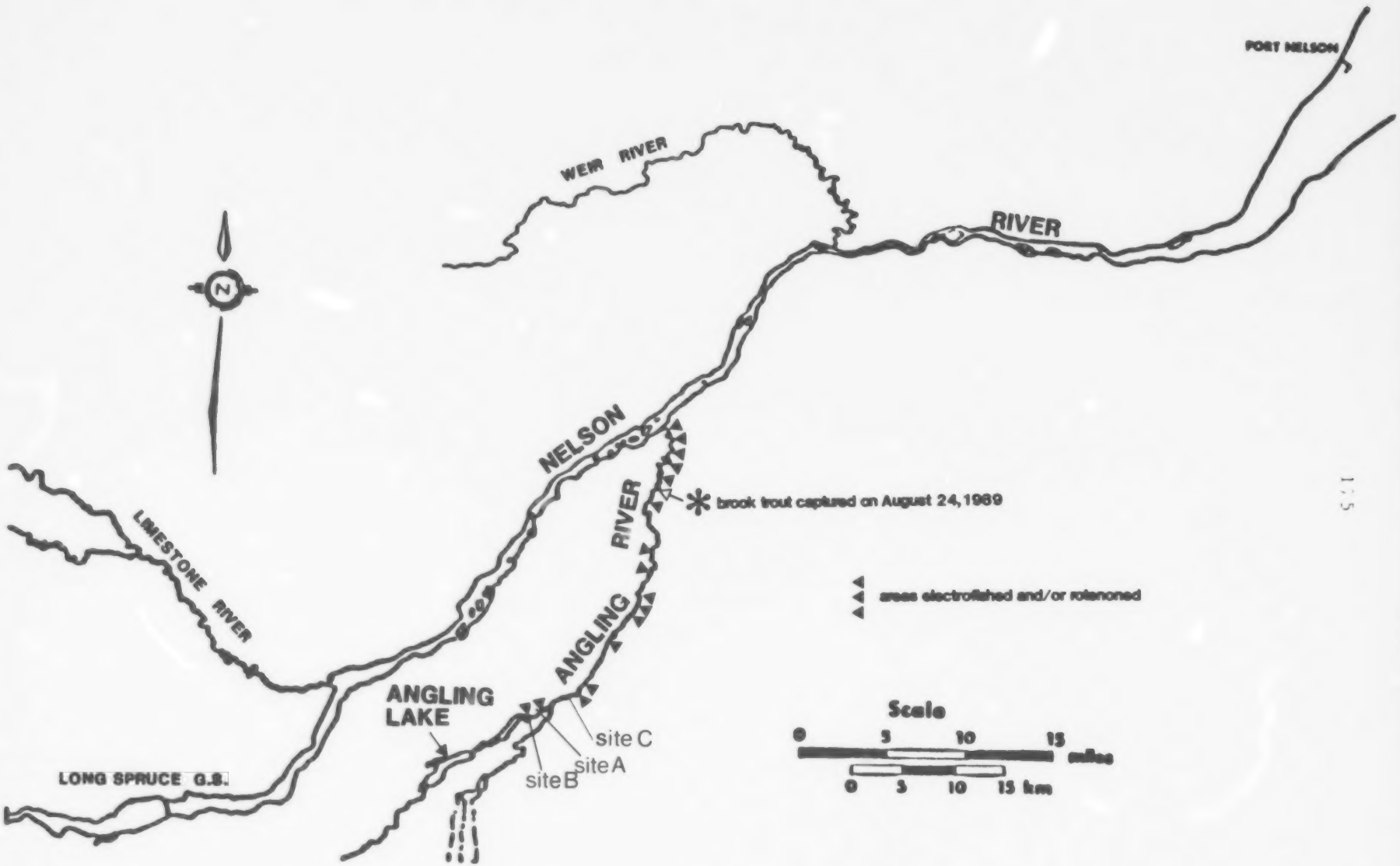

Fig. 4. Sampling locations on the Angling River in August, 1989.

the course of the river. Use of the 15 m x 1.5 m beach seine was limited by suitable depth and substrate. Species other than sturgeon were enumerated only, with general observations on size and maturity.

Angling Lake Telemetry

Sturgeon tagged with radio transmitters in Angling Lake in 1988 were monitored by helicopter as described, and reported to April, 1989, in Swanson et al. (1990). From May to October, 1989 Fisheries Branch staff monitored the transmitters; from November, 1989 to May, 1990 Regional Services staff in Gillam and Sundance continued the monitoring. Transmitter frequencies 48.061 Mhz and 48.222 Mhz which were tagged to sturgeon in 1986, and located in Angling Lake during this study, were also monitored and reported.

RESULTS

L.S.G.S. Spillway Netting

Fourteen sturgeon were captured between June 16 and 27, 1989. Six were sacrificed, three of which were examined for parasites at the University of Manitoba (Appendix 2). The remaining three were donated to Mr. James Brown of the Simon Fraser University for mt DNA analysis; results are pending. Physical information (length, weight, sex, age) for all 14 fish is presented in Table 1, along with tagging information.

Of the 14 sturgeon captured, sex could be determined for 8: 2 females and 6 males. Two of the males were ripe and four were spent. Both females were carrying eggs but were not developed enough to spawn in 1989 (Dr. T. Dyck, University of Manitoba, pers. comm.).

Figure 5 shows the number of sturgeon caught daily, including recaptures. A mark-recapture analysis (Schumacher-Eschmeyer) shows a small discrete population, 95% confidence interval of 14-15 sturgeon. Daily temperatures are also recorded in Figure 5.

Five sturgeon were retagged with floy tags after removing the disc tags. Wounds resulting from the disc tag and net entanglements were treated with isopropyl alcohol. Disc tag number 0173 was found in a gill net without the fish on June 17, 1989, one day after it was tagged.

Table 1. Tagging data for sturgeon caught below the L.S.G.S. in the Nelson River in June, 1989.

Location	Date	Length Total (cm)	Length Fork (cm)	Weight	Sex	Age	Tag Number	Comments
L.S.G.S.	June 16	120.00	111.50	7.30	M	29	sacrificed	
L.S.G.S.	June 16	123.00	112.00	10.00	F	39	sacrificed	samples to U of M
L.S.G.S.	June 16	89.00	82.50	3.60	M	31	Disc 0173	disc found in net
L.S.G.S.	June 16	89.50	82.00	4.40	-	22	Disc 0172	2 retagged UMX00830/31 on June 21
L.S.G.S.	June 16	104.00	99.50	5.50	M	19	sacrificed	samples to U of M
L.S.G.S.	June 16	113.00	105.50	7.90	-	34	Disc 0097	7 retagged UMX00669/68 on June 20
L.S.G.S.	June 16	109.50	96.50	5.50	-	14	Disc 0098	8
L.S.G.S.	June 16	137.00	131.00	14.10	F	45	sacrificed	
L.S.G.S.	June 17	108.50	99.50	7.30	M	22	Disc 0171	1 retagged UMX00833/34 on June 24
L.S.G.S.	June 19	86.00	78.00	3.20	M	20	UMX00673/74	74
L.S.G.S.	June 21	116.00	107.00	8.30	M	30	sacrificed	samples to U of M
L.S.G.S.	June 21	86.00	75.40	2.90	-	17	UMX00828/29	29
L.S.G.S.	June 22	122.00	110.00	8.10	-	38	UMX00832	
L.S.G.S.	June 24	84.30	76.00	3.10	-	22	UMX00838/39	39

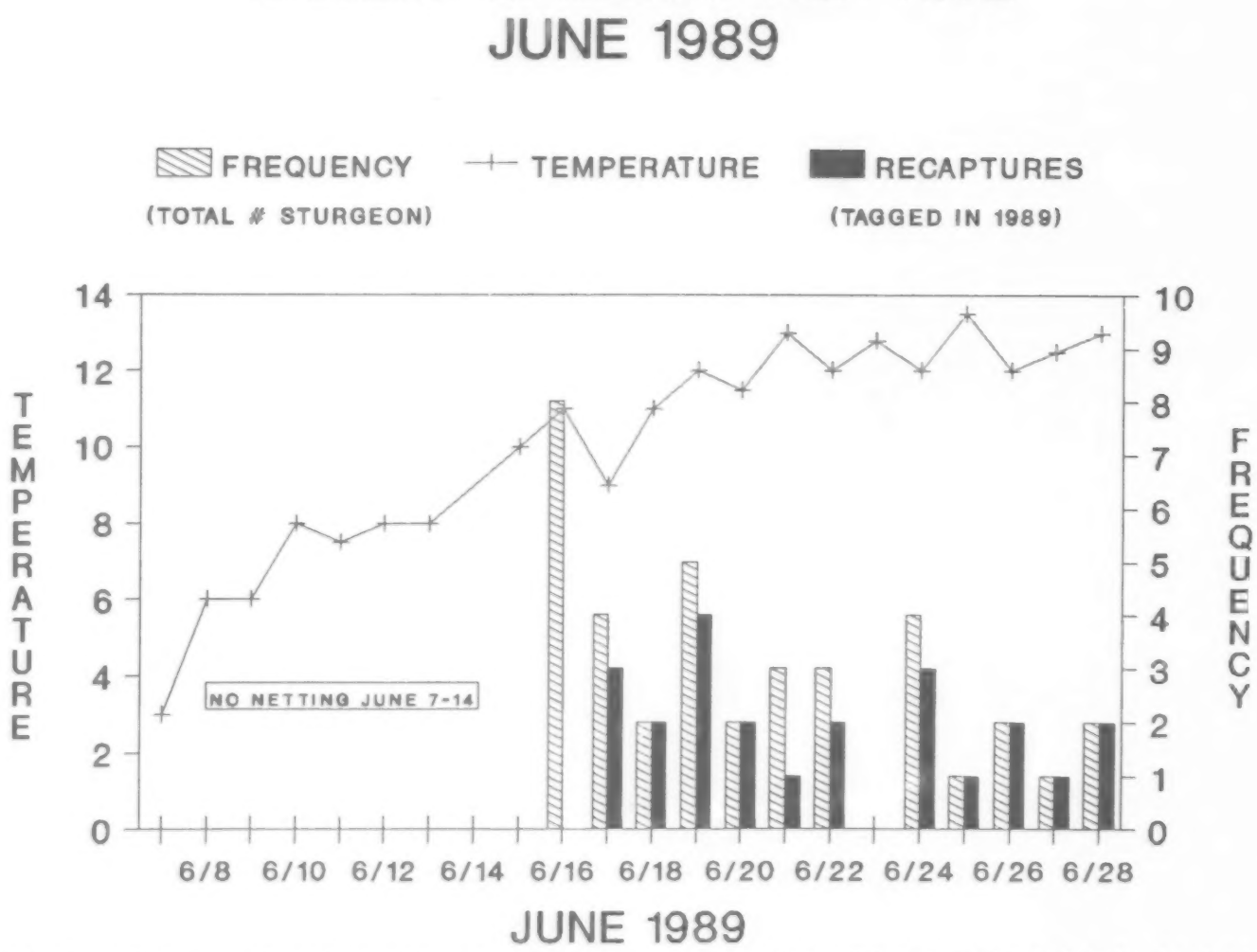

Fig. 5. Daily catch information of sturgeon caught in gill nets below the L.S.G.S. in June 1989. Temperatures are presented daily in °C.

Angling Lake

During the sampling period, July 6-17, 1989, at least three gear types were used at all times. No young-of-the-year or juvenile sturgeon were captured. The light traps and pop-up traps caught no fish at all. Seining and electrofishing captured nine species; yellow perch, spottail shiner and log perch were most common (Figure 6). Small mesh gill netting captured six species; northern pike, walleye and lake whitefish were most common (Figure 7). Species found and frequency of capture are similar to those of gill netting conducted in 1987 (Figure 7).

The gills and all internal organs of three adult sturgeon which were captured using large mesh gill nets were examined at the University of Manitoba. Isozyme results were not available at the time of writing. Length, weight, sex, stomach contents and parasites are presented for each fish in Appendix 3.

Angling River

No sturgeon were captured by any of the sampling techniques used in the Angling River in August of 1989. Lake whitefish, northern pike and walleye were captured during gill netting (Figure 8). All fish caught in gill nets were adult size; approximately half of the whitefish were carrying eggs. One brook trout was captured by electrofishing (Figure 4). It weighed approximately 1.2 kg and was 300 mm in length. Other species captured by electrofishing or rotentone included longnose dace, slimy sculpin, yellow perch, burbot and spottail shiner. The preset hoop nets caught no fish.

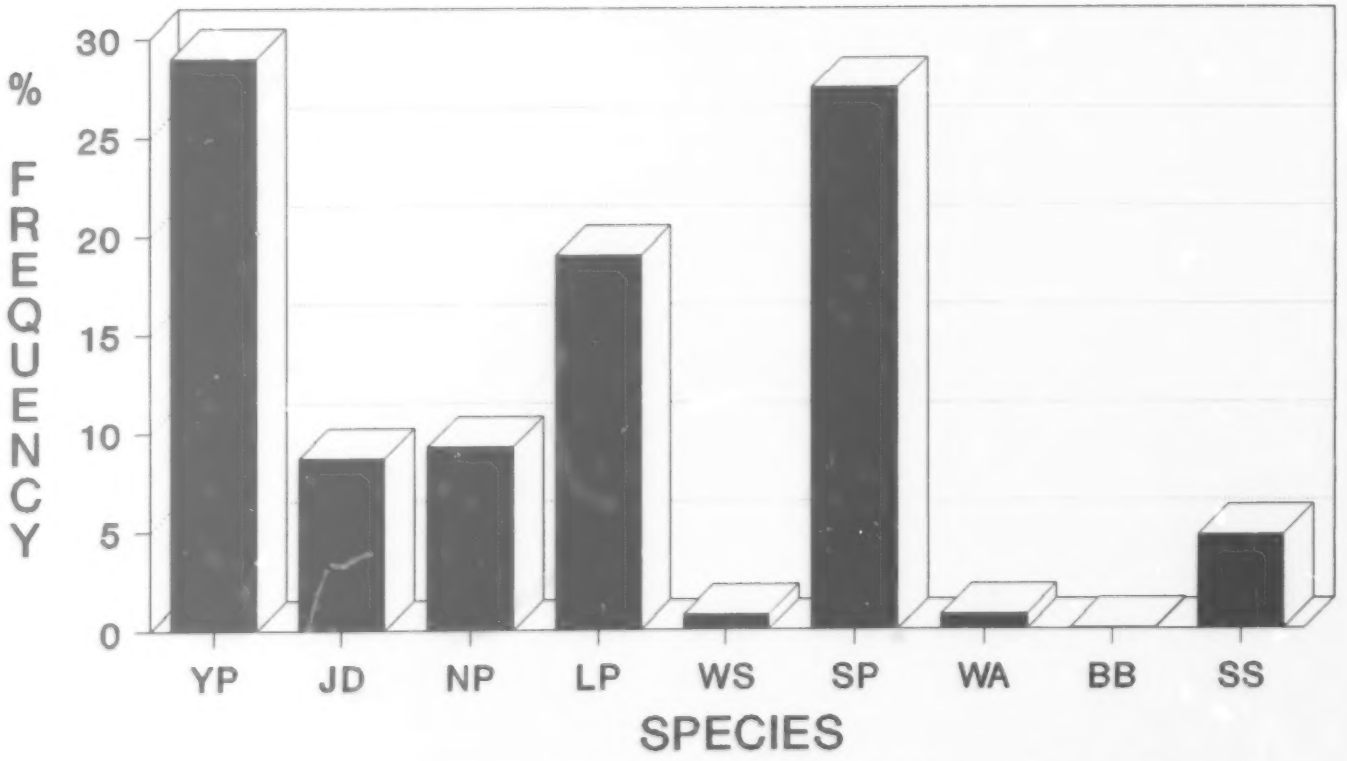

Fig 6. Additional species caught in Angling Lake in 1989 by electroshocking and seining. YP=yellow perch, JD=johnny darter, NP=northern pike, LP=log perch, WS=white sucker, SP=spottail shiner, WA=walleye, BB=burbot, SS=slimy sculpin.

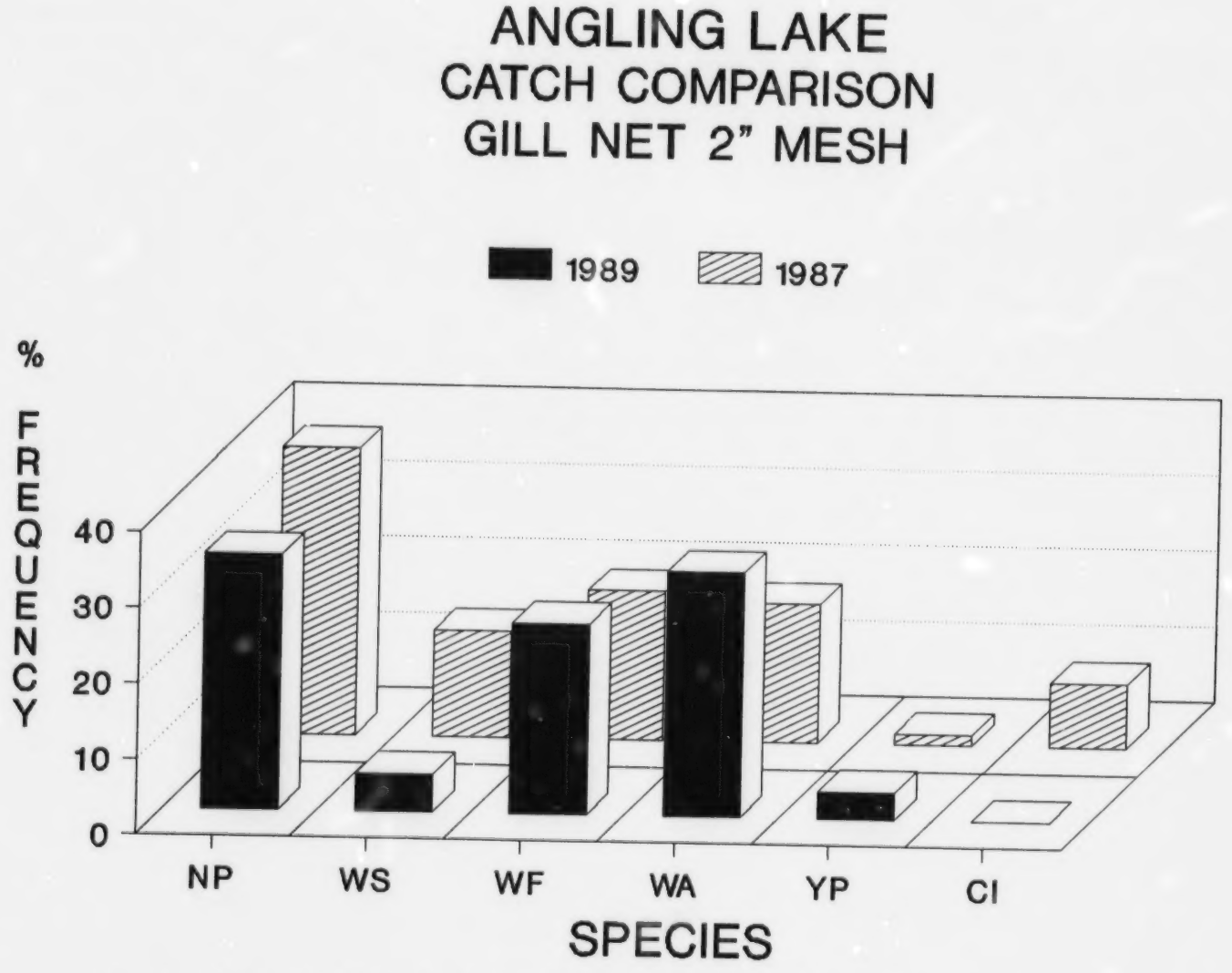

Fig. 7. Additional species caught in 5.1 cm gill nets in Angling Lake in 1989 and compared to species caught in Angling Lake in 1987.
NP= northern pike, WS=white sucker, WF=lake whitefish, WA=walleye, YP=yellow perch, CI=cisco.

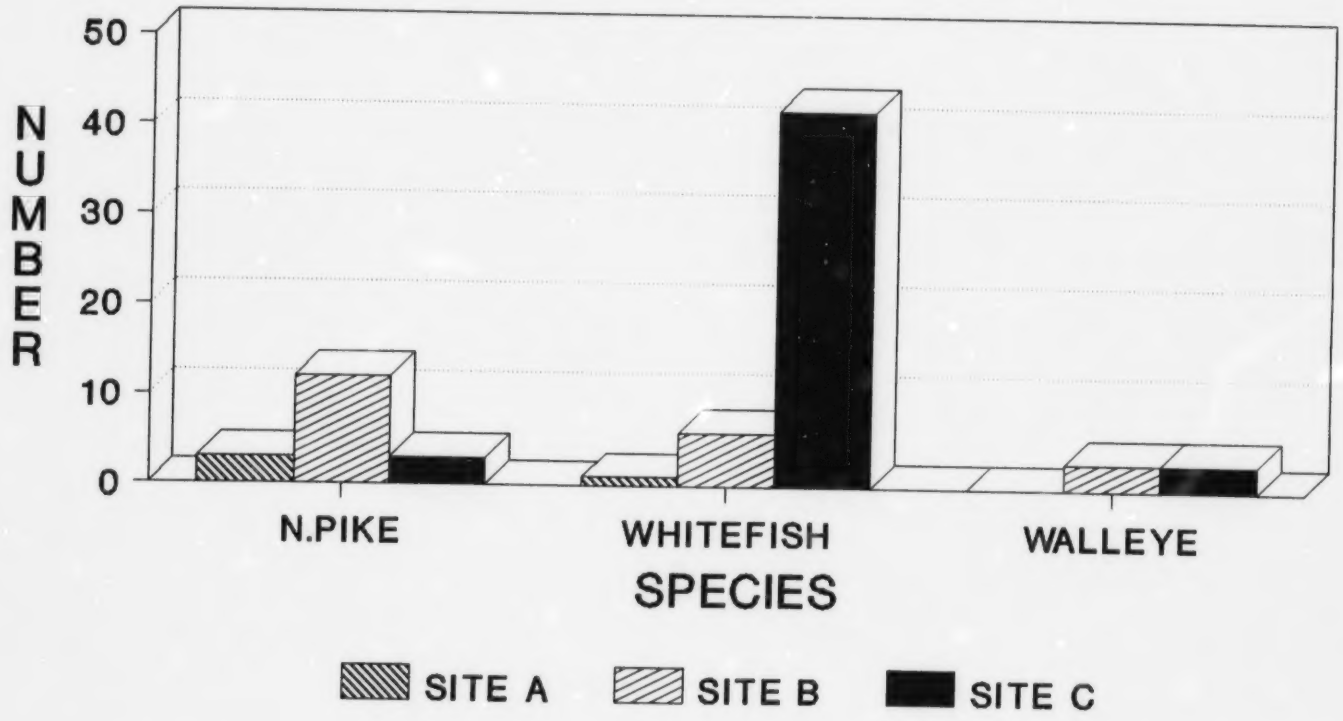

Fig. 8. Results of preset gill nets in the Angling River, August, 1989.

Angling Lake Telemetry

Tracking flights included in this report are from May 1, 1989 to May 14, 1990. There were 17 flights during this period. Individual sturgeon movements are shown in Figures 9-20. All 10 sturgeon tagged in Angling Lake (49 Mhz range) were recorded in all 17 flights. Two previously radio tagged sturgeon, 48.222 Mhz and 48.061 Mhz which moved into Angling Lake in 1986, were monitored during the first 15 flights, but could not be located during the last two (Figures 9 and 10). Both of these sturgeon remained in the same areas as reported during previous monitoring (Swanson et al. 1990). It is believed that the radio transmitters finally lost power.

Tag frequency 49.468 Mhz (Figure 11) was consistently tracked in the deep, center portion of Angling Lake throughout the tracking period. Only small 0.5 km movements in this area were detected.

Tag frequency 49.489 Mhz (Figure 12) resided mainly in an area just west of the deep portion of the lake. It remained in this portion of the lake moving at most 1.5 km in and around the area.

Tag frequency 49.508 Mhz (Figure 13) remained in the deepest portion of the lake for the whole of the tracking period with only 1 km movements.

Tag frequency 49.528 Mhz (Figure 14) remained in the deepest portion of the lake most of the time, with only slight wanderings (0.5 km) to the west.

Tag Frequency 49.549 Mhz (Figure 15) remained for the most part in the deepest area of the lake, however it did move slightly into the narrows of the lake on June 7, 1989 and on March 12 and

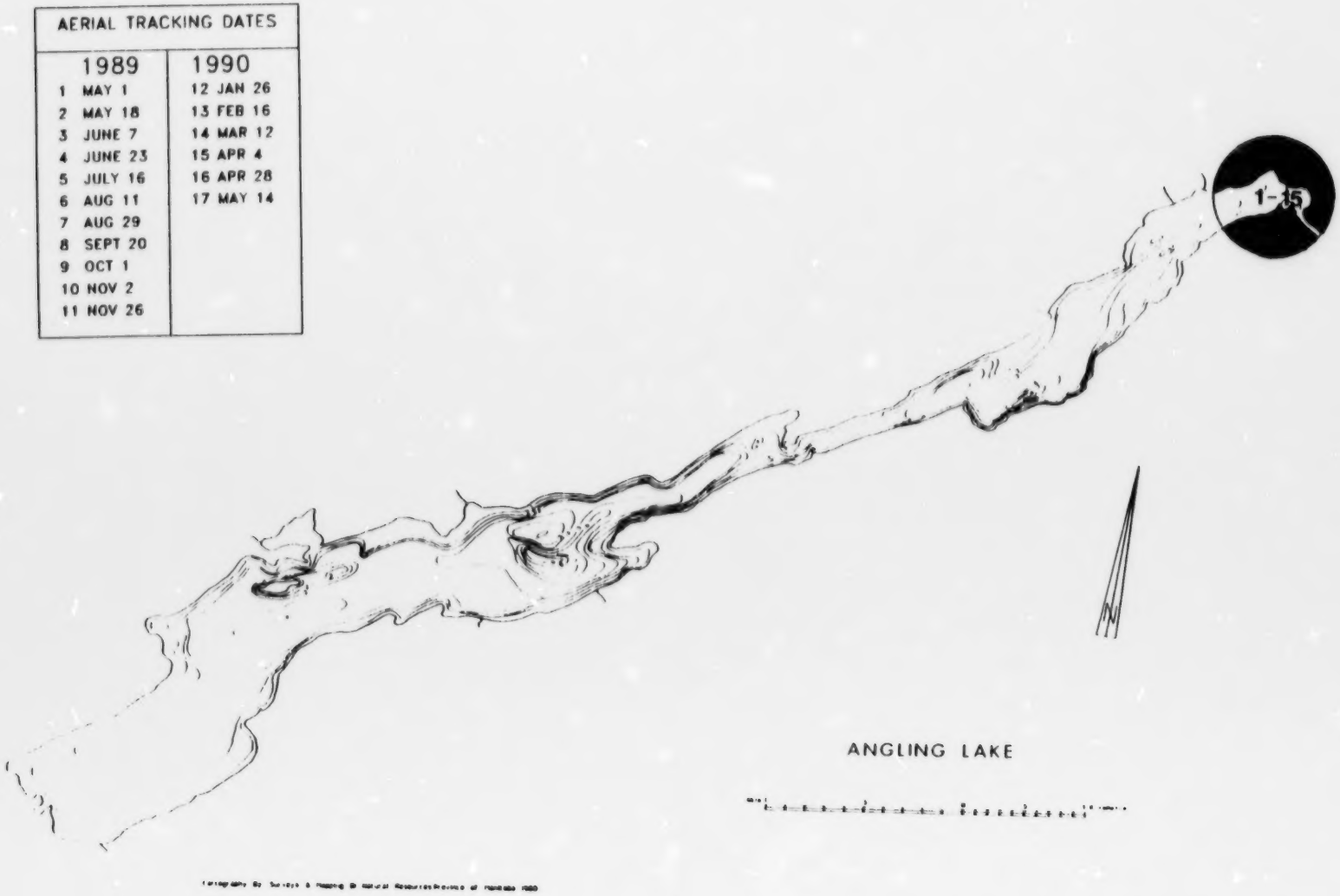

Fig. 9. Movements of sturgeon radio tagged 48.061 Mhz in 1989-90.

AERIAL TRACKING DATES	
1989	1990
1 MAY 1	12 JAN 26
2 MAY 18	13 FEB 16
3 JUNE 7	14 MAR 12
4 JUNE 23	15 APR 4
5 JULY 16	16 APR 28
6 AUG 11	17 MAY 14
7 AUG 29	
8 SEPT 20	
9 OCT 1	
10 NOV 2	
11 NOV 26	

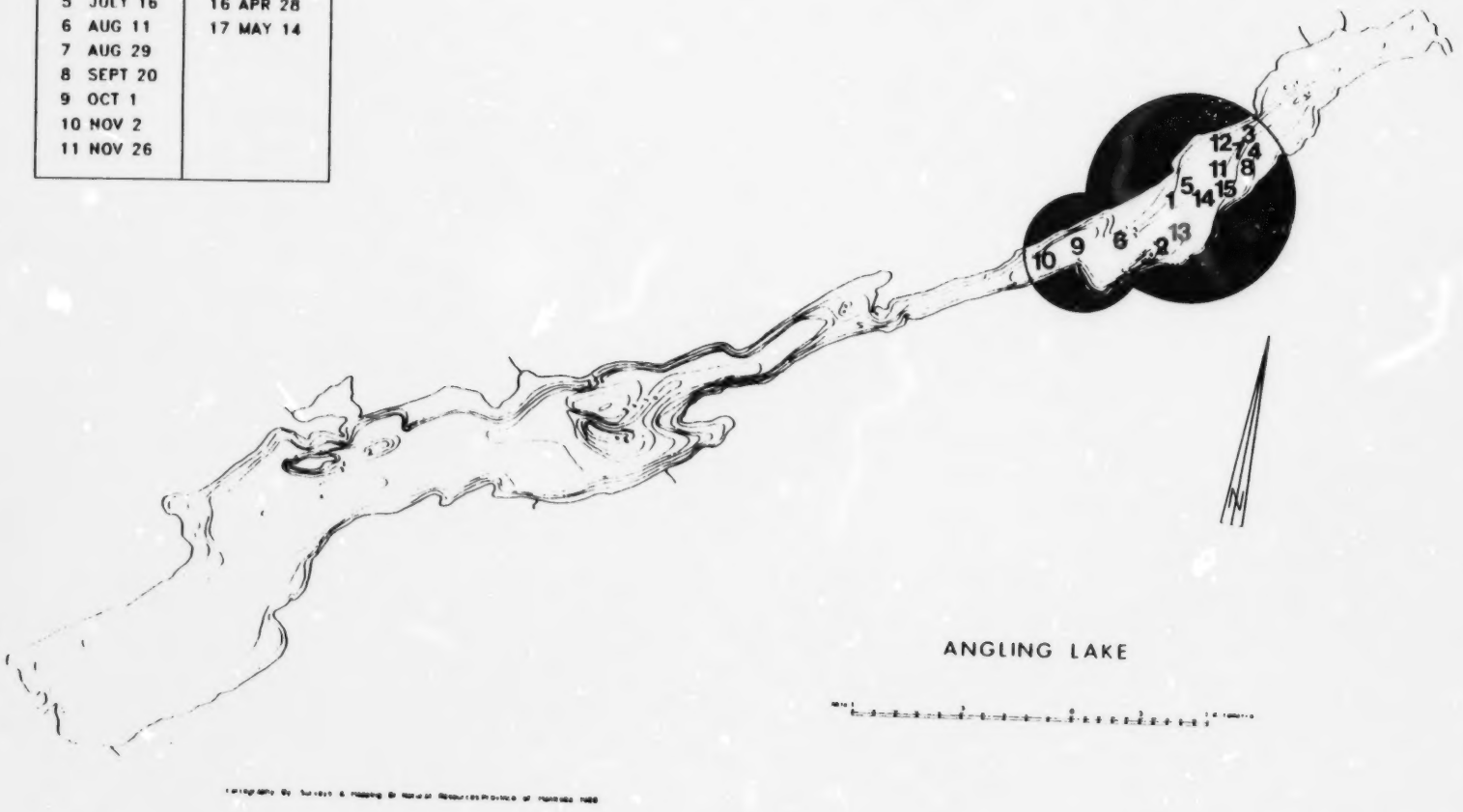

Fig. 10. Movements of sturgeon radio tagged 48.222 Mhz in 1989-90.

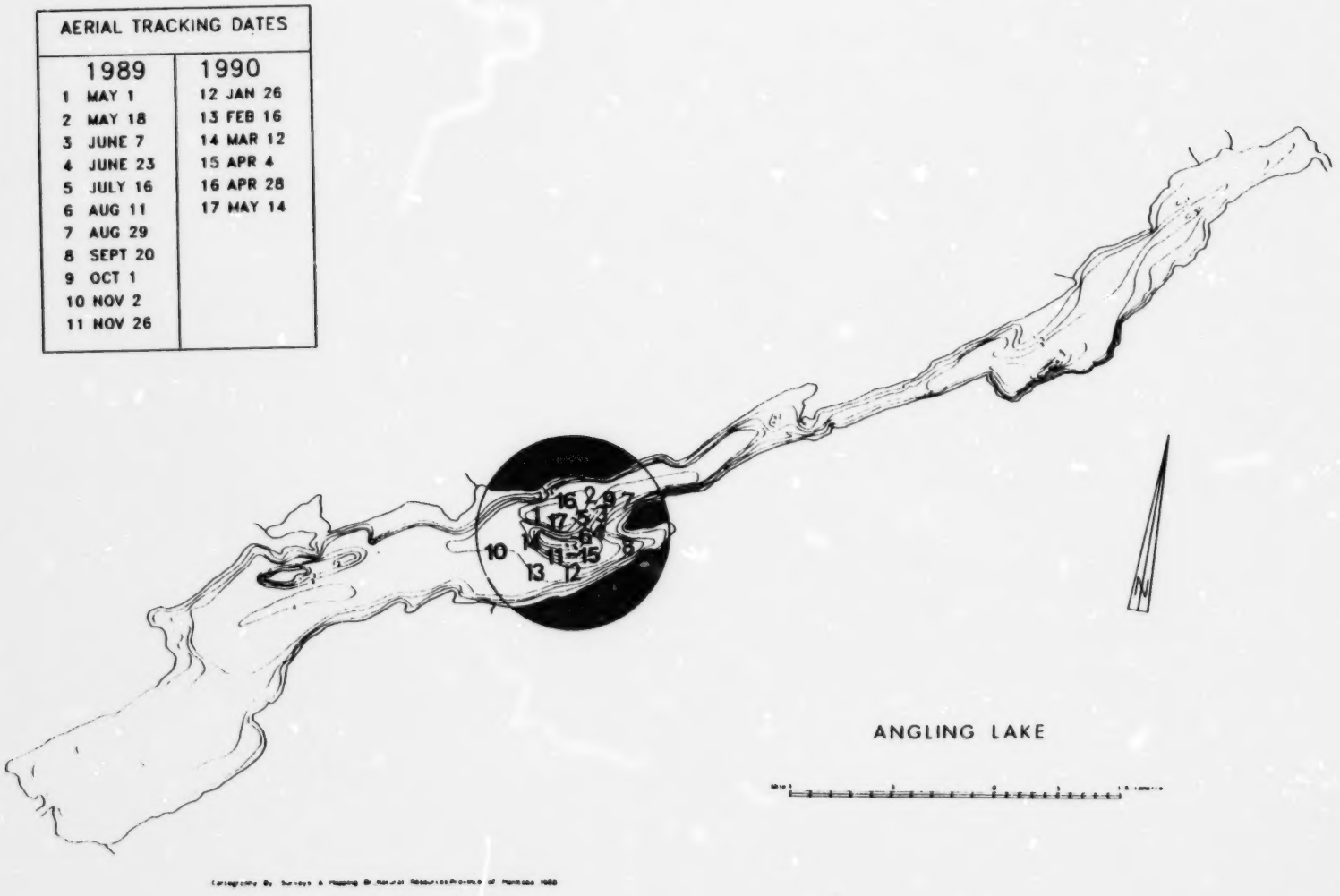

Fig. 11. Movements of sturgeon radio tagged 49.468 Mhz in 1989-90.

AERIAL TRACKING DATES	
1989	1990
1 MAY 1	12 JAN 26
2 MAY 18	13 FEB 16
3 JUNE 7	14 MAR 12
4 JUNE 23	15 APR 4
5 JULY 16	16 APR 28
6 AUG 11	17 MAY 14
7 AUG 29	
8 SEPT 20	
9 OCT 1	
10 NOV 2	
11 NOV 26	

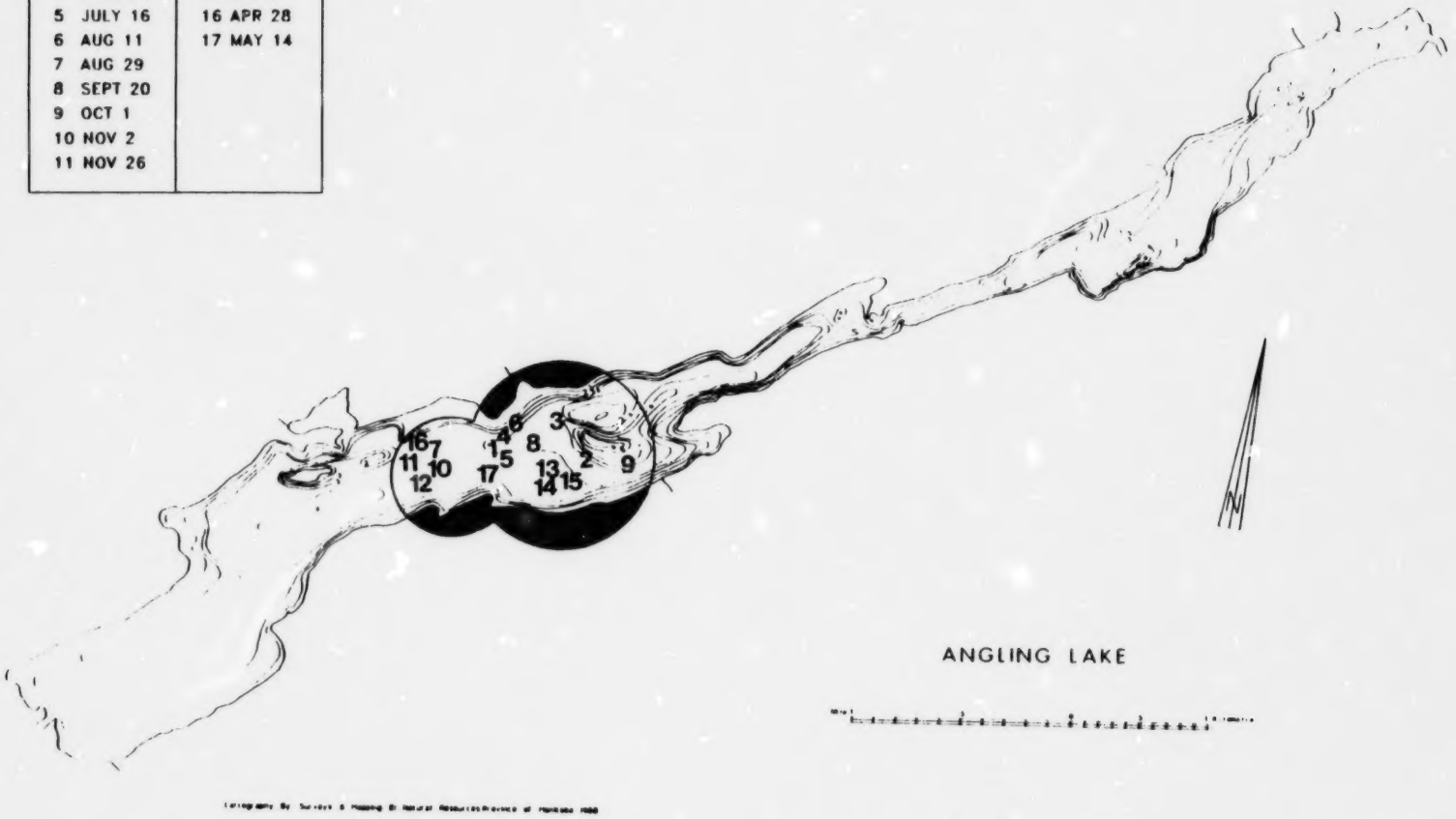

Fig. 12. Movements of sturgeon radio tagged 49.489 Mhz in 1989-90.

AERIAL TRACKING DATES	
1989	1990
1 MAY 1	12 JAN 26
2 MAY 18	13 FEB 16
3 JUNE 7	14 MAR 12
4 JUNE 23	15 APR 4
5 JULY 16	16 APR 28
6 AUG 11	17 MAY 14
7 AUG 29	
8 SEPT 20	
9 OCT 1	
10 NOV 2	
11 NOV 26	

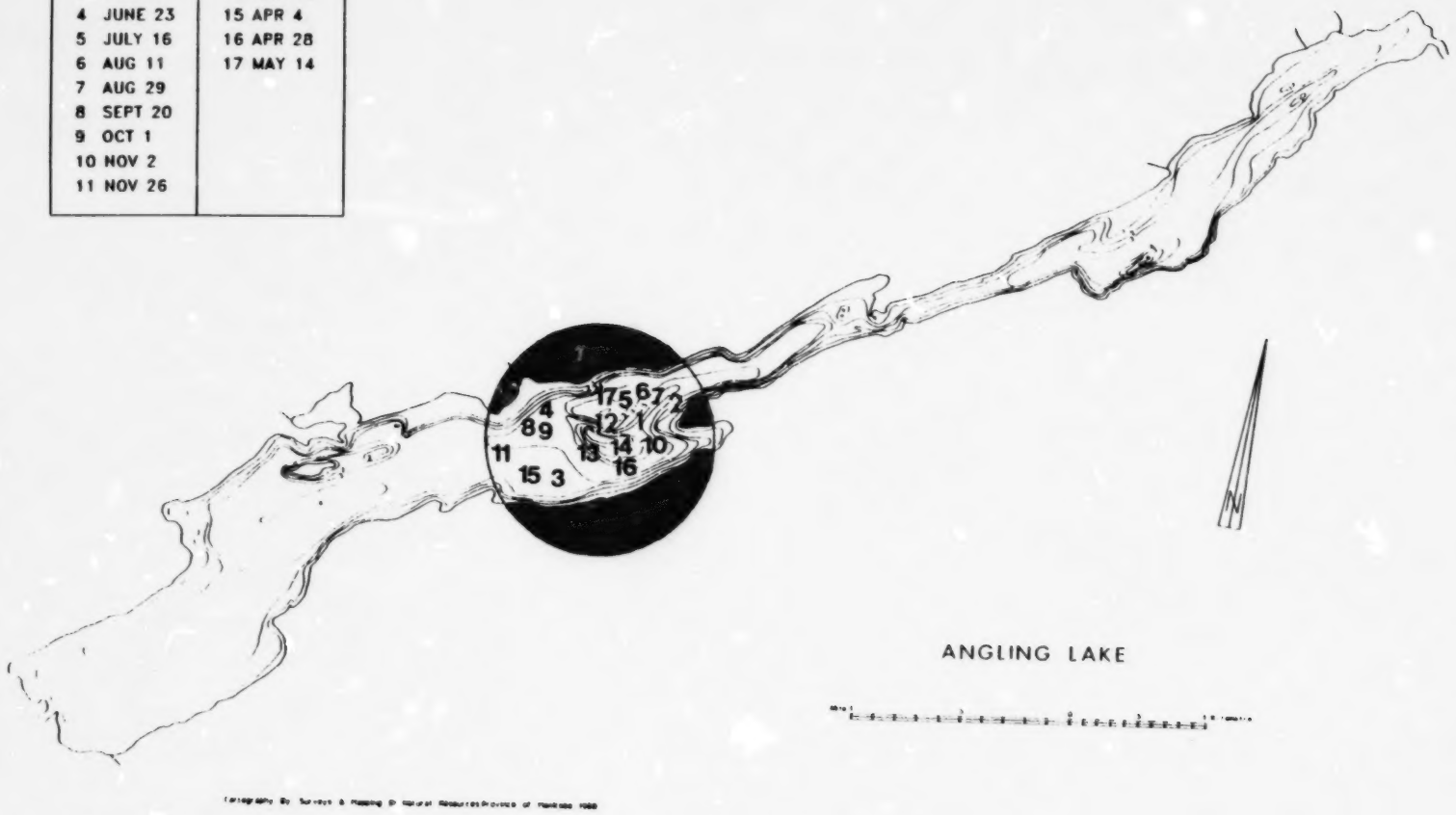

Fig. 13. Movements of sturgeon radio tagged 49.508 Mhz in 1989-90.

AERIAL TRACKING DATES	
1989	1990
1 MAY 1	12 JAN 26
2 MAY 18	13 FEB 16
3 JUNE 7	14 MAR 12
4 JUNE 23	15 APR 4
5 JULY 16	16 APR 28
6 AUG 11	17 MAY 14
7 AUG 29	
8 SEPT 20	
9 OCT 1	
10 NOV 2	
11 NOV 26	

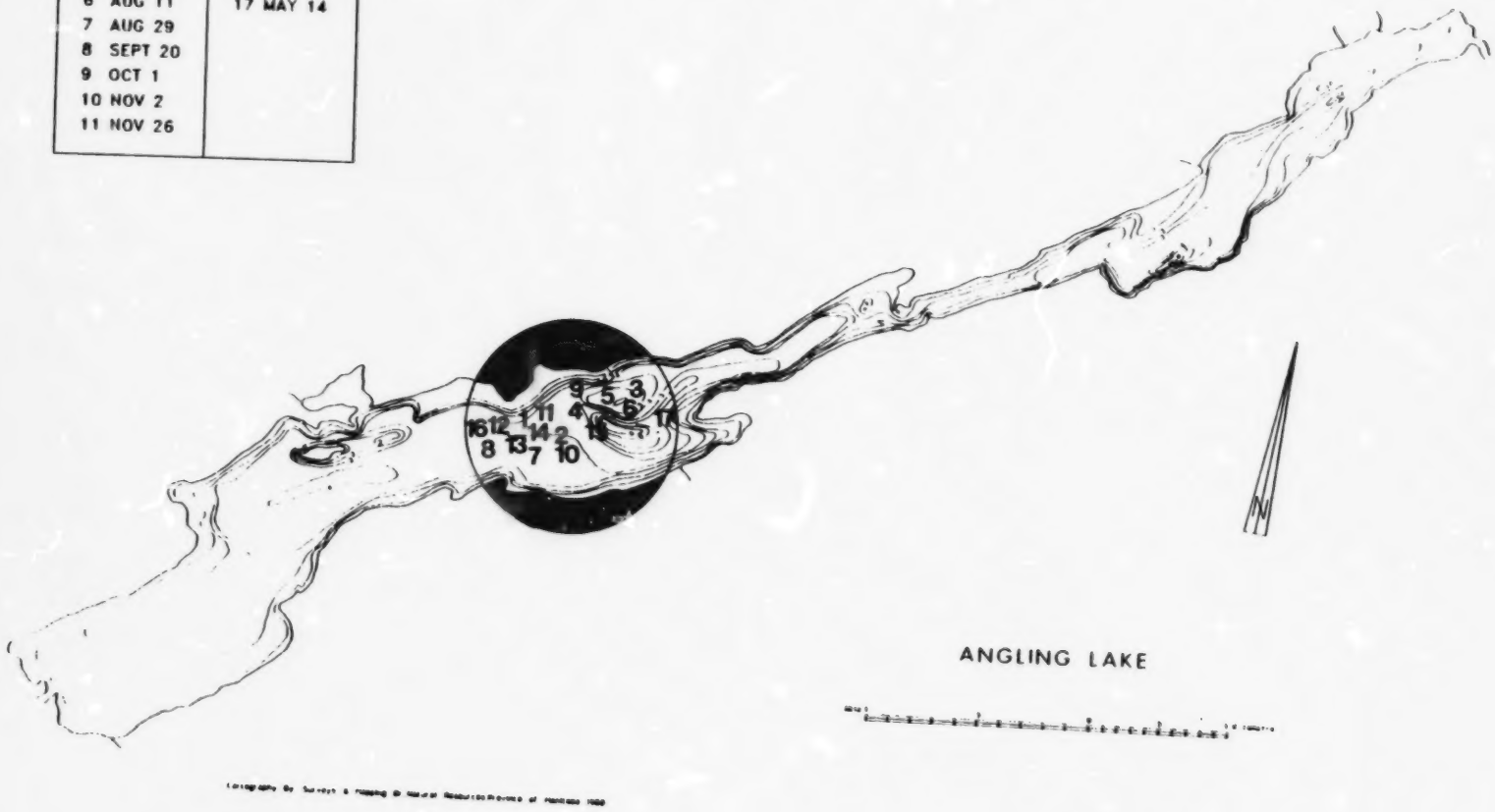

Fig. 14. Movements of sturgeon radio tagged 49.528 Mhz in 1989-90.

AERIAL TRACKING DATES	
1989	1990
1 MAY 1	12 JAN 26
2 MAY 18	13 FEB 16
3 JUNE 7	14 MAR 12
4 JUNE 23	15 APR 4
5 JULY 16	16 APR 28
6 AUG 11	17 MAY 14
7 AUG 29	
8 SEPT 20	
9 OCT 1	
10 NOV 2	
11 NOV 26	

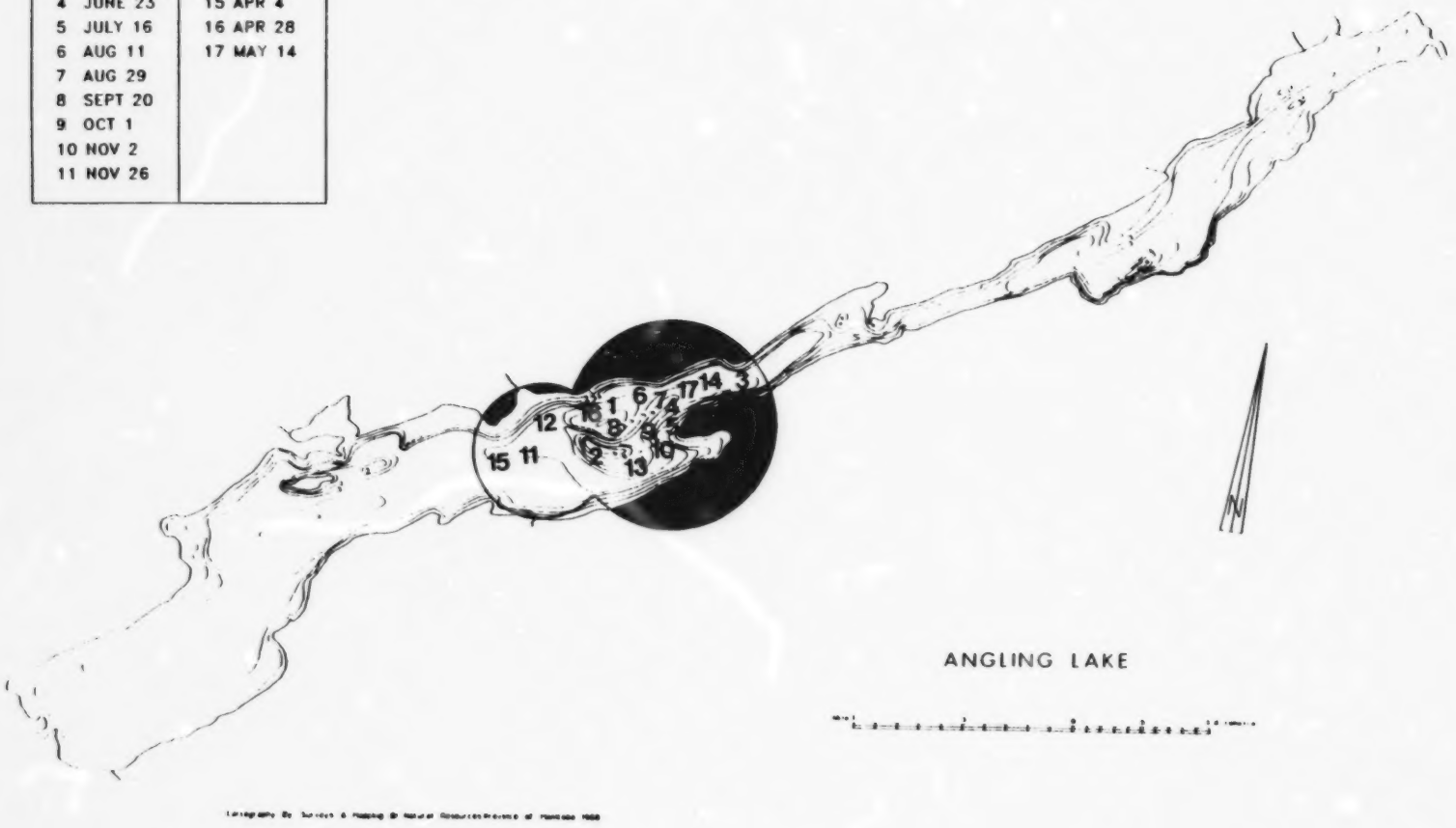

Fig. 15. Movements of sturgeon radio tagged 49.549 Mhz in 1989-90.

May 14, 1990.

Tag frequency 49.568 Mhz (Figure 16) moved considerably more than those fish mentioned previously. On May 1, 1989 it was in the deepest portion, then it was found 4 km downstream towards the outflow. On June 7 and June 23, 1989 it was back in the deep portion and on July 16, 1989 had moved to the inflow basin and remained in this area until April 28, 1990. The last flight showed that it had moved approximately 1 km northeast of this area (May 14, 1990).

Tag frequency 49.589 Mhz (Figure 17) resided near the island in the southeast basin for the duration of the tracking flights. The largest movements were less than a kilometre.

Tag frequency 49.608 Mhz (Figure 18) was in Angling Lake on May 1 and May 18, 1989. By June 7 it was 20 km downstream in the Angling River and by July 16 it was in the Nelson River, 10 km downstream of Angling River mouth. It moved back up to the mouth of the Angling River by July 16 and remained there until October 1. On November 2 it was at the mouth of the Weir River (25 km downstream) and as of the last tracking flight, May 14, 1990, it was another 20 km downstream.

Tag frequency 49.628 Mhz (Figure 19) generally remained in the deepest portion of the lake, but moved out of this area three times. On May 3, 1989 it was located downstream (3 km) in the narrows area; on October 1, 1989, it was located upstream 3 km; and on November 26, 1989 it was again upstream, 2 km. It remained in the deepest portion to the last tracking flight (May 14, 1990).

Tag frequency 49.448 Mhz (Figure 20) remained in the deepest

AERIAL TRACKING DATES	
1989	1990
1 MAY 1	12 JAN 26
2 MAY 18	13 FEB 16
3 JUNE 7	14 MAR 12
4 JUNE 23	15 APR 4
5 JULY 16	16 APR 28
6 AUG 11	17 MAY 14
7 AUG 29	
8 SEPT 20	
9 OCT 1	
10 NOV 2	
11 NOV 26	

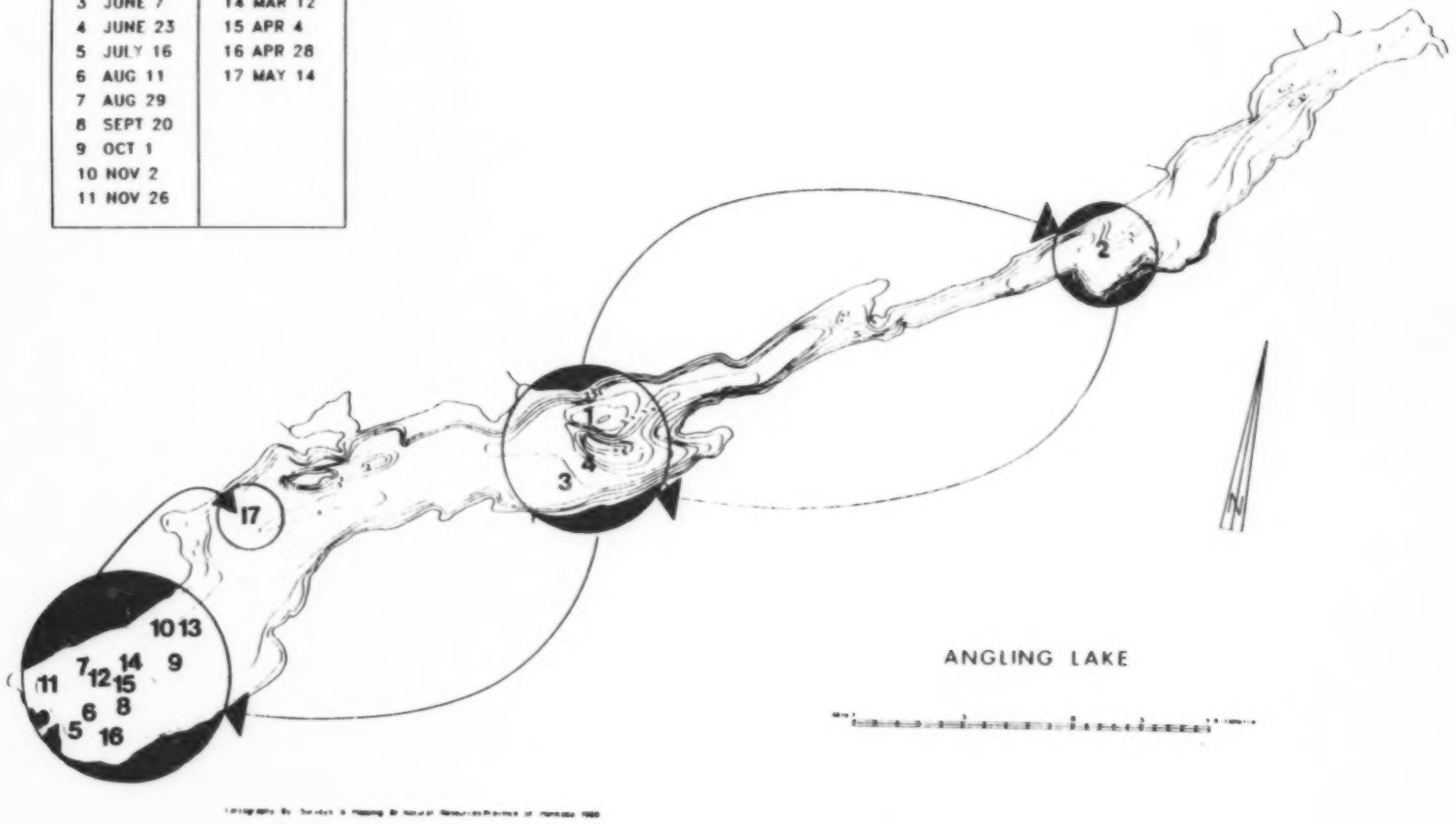

Fig. 16. Movements of sturgeon radio tagged 49.568 Mhz in 1989-90.

AERIAL TRACKING DATES	
1989	1990
1 MAY 1	12 JAN 26
2 MAY 18	13 FEB 16
3 JUNE 7	14 MAR 12
4 JUNE 23	15 APR 4
5 JULY 16	16 APR 28
6 AUG 11	17 MAY 14
7 AUG 29	
8 SEPT 20	
9 OCT 1	
10 NOV 2	
11 NOV 26	

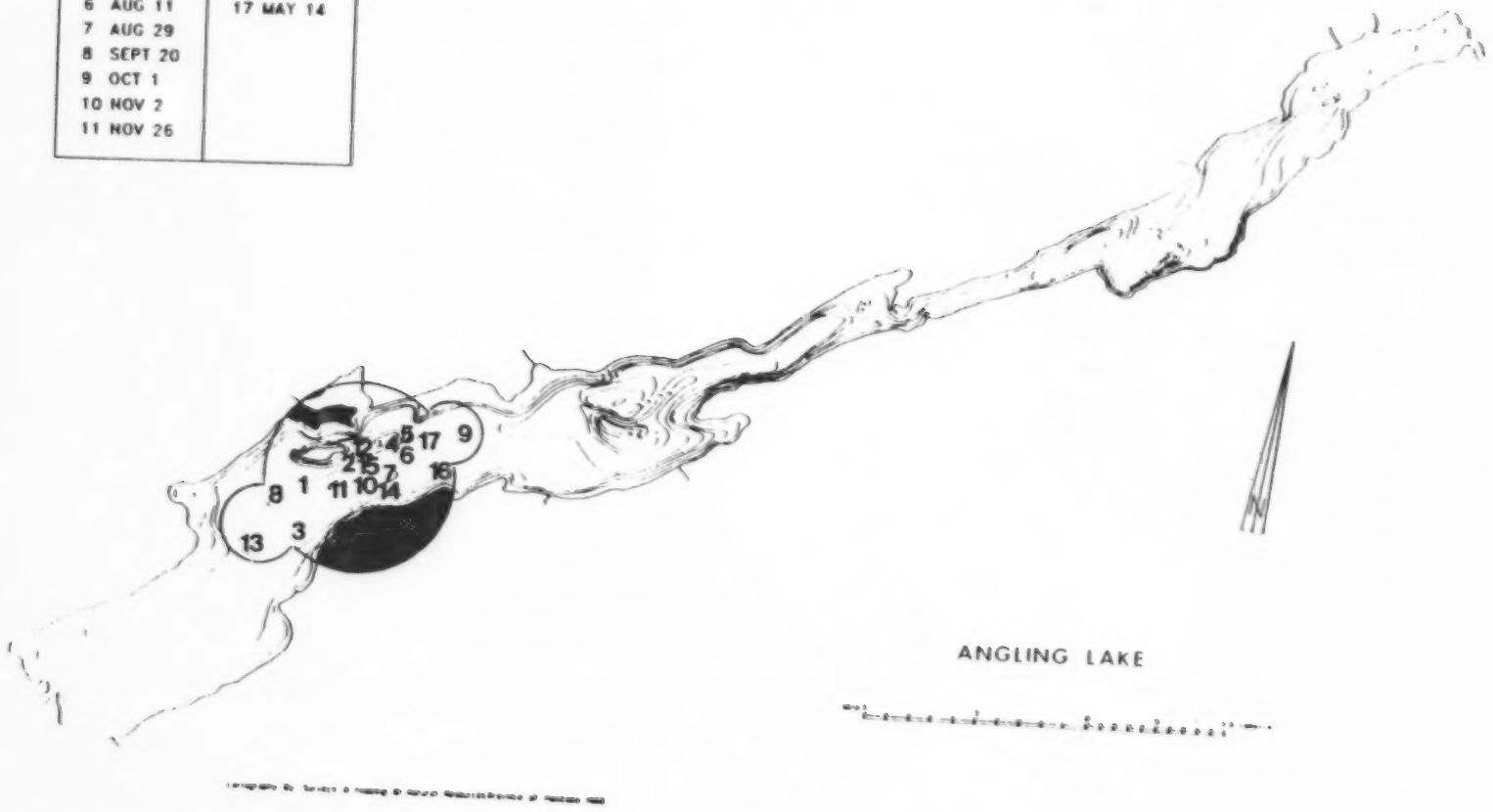

Fig. 17. Movements of sturgeon radio tagged 49.589 Mhz in 1989-90.

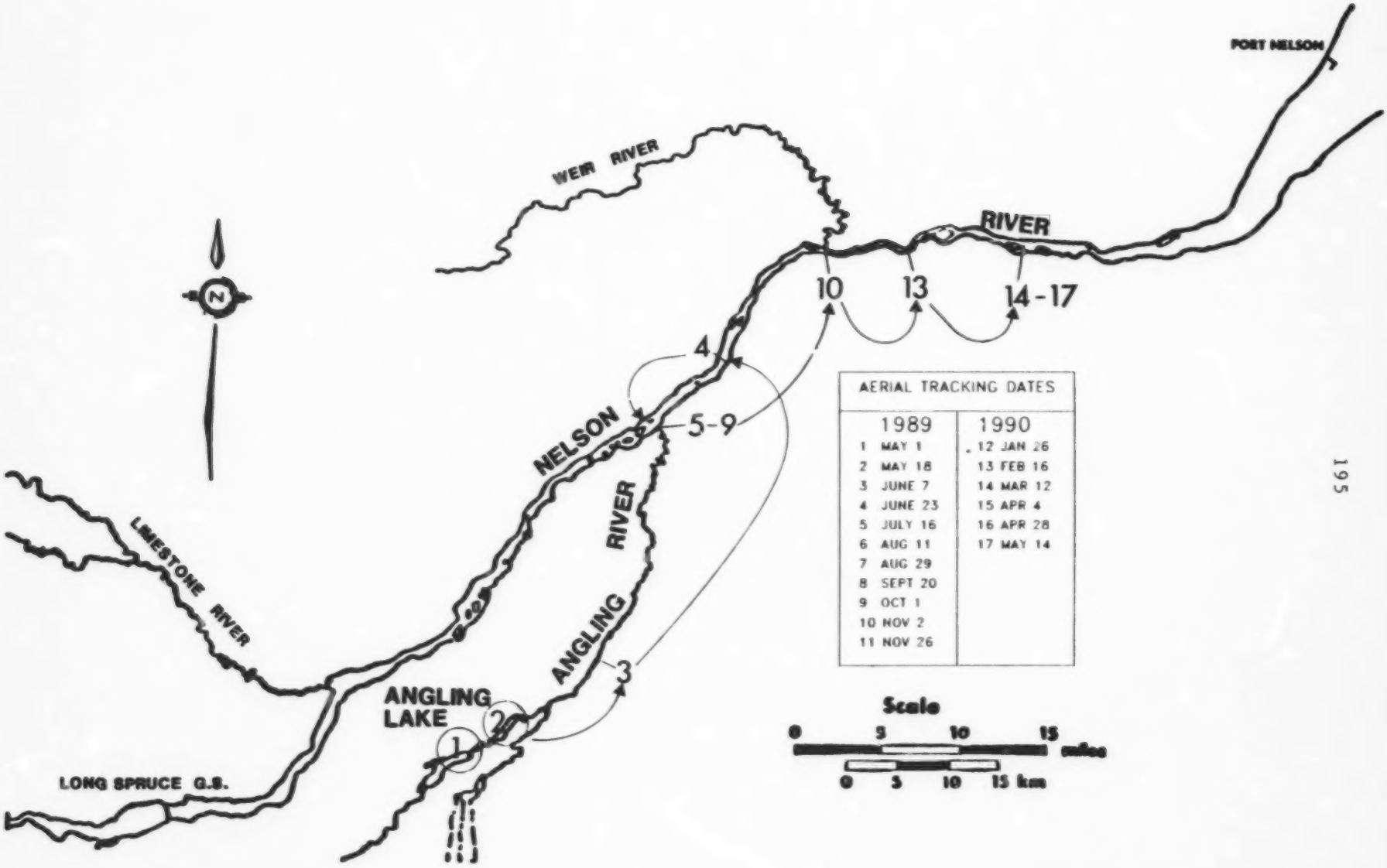

Fig. 18. Movements of sturgeon radio tagged 49.608 Mhz in 1989-90.

AERIAL TRACKING DATES	
1989	1990
1 MAY 1	12 JAN 26
2 MAY 18	13 FEB 16
3 JUNE 7	14 MAR 12
4 JUNE 23	15 APR 4
5 JULY 16	16 APR 28
6 AUG 11	17 MAY 14
7 AUG 29	
8 SEPT 20	
9 OCT 1	
10 NOV 2	
11 NOV 26	

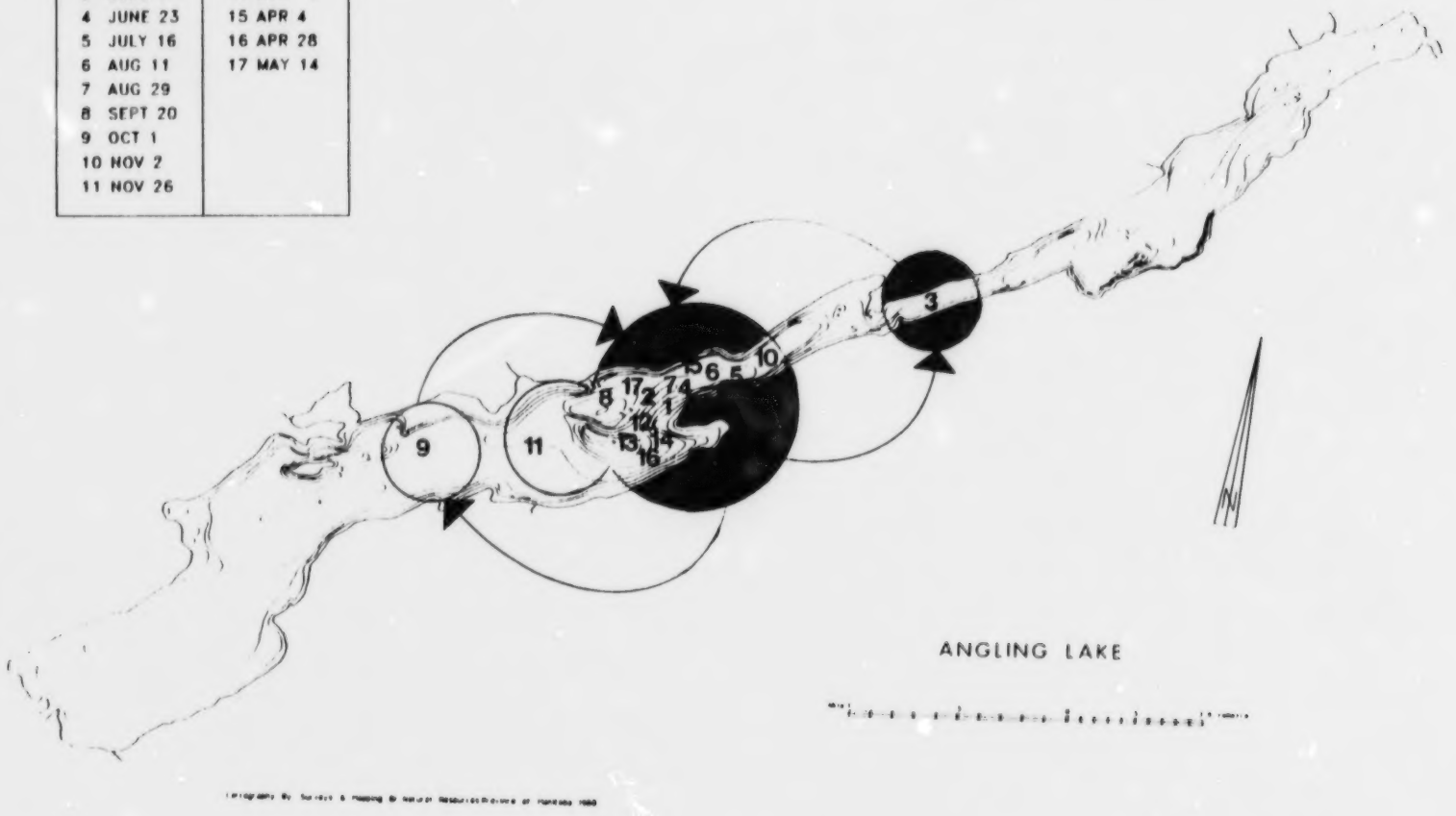

Fig. 19. Movements of sturgeon radio tagged 49.628 Mhz in 1989-90.

AERIAL TRACKING DATES	
1989	1990
1 MAY 1	12 JAN 26
2 MAY 18	13 FEB 16
3 JUNE 7	14 MAR 12
4 JUNE 23	15 APR 4
5 JULY 16	16 APR 28
6 AUG 11	17 MAY 14
7 AUG 29	
8 SEPT 20	
9 OCT 1	
10 NOV 2	
11 NOV 26	

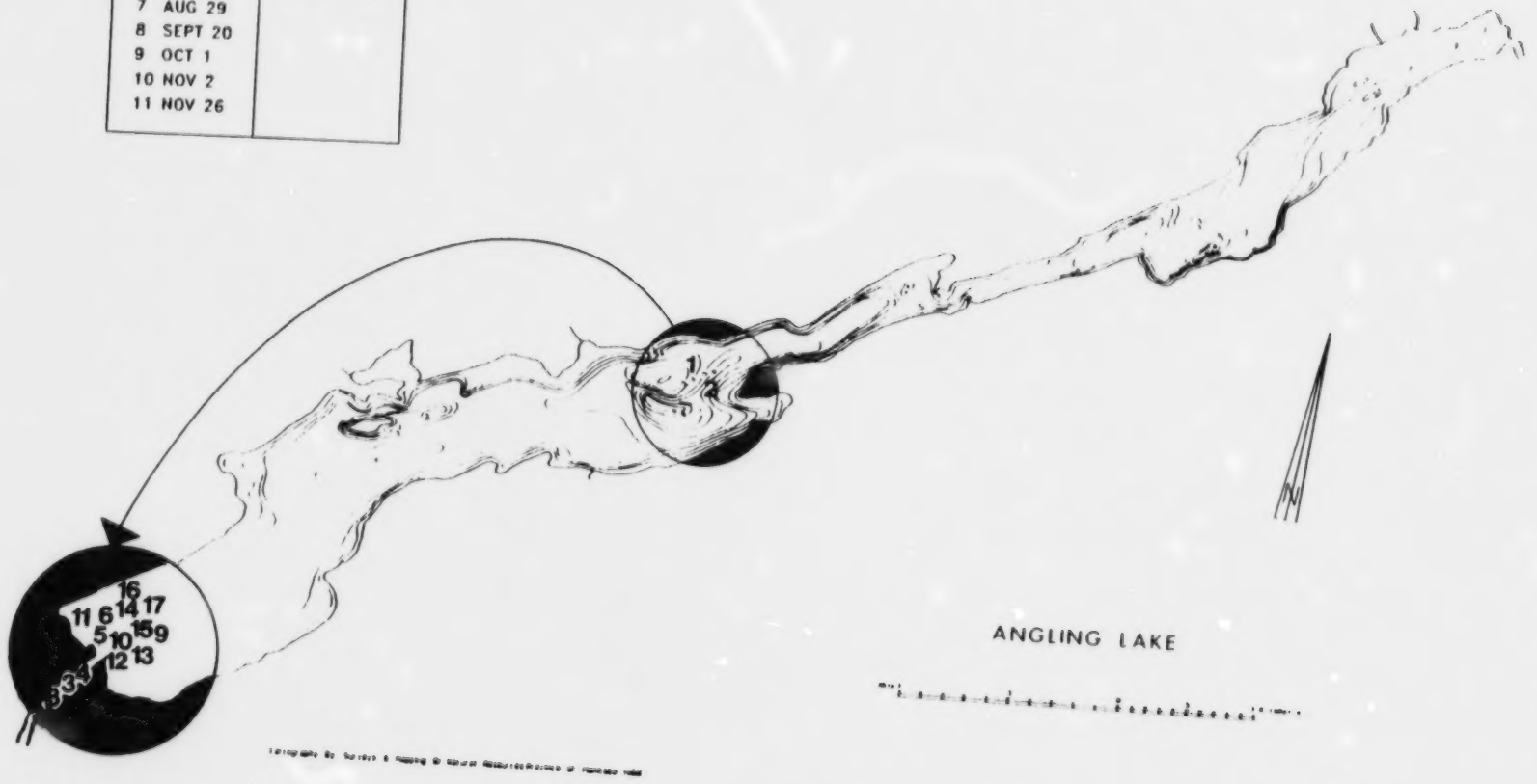

Fig. 20. Movements of sturgeon radio tagged 49.448 Mhz in 1989-90.

center portion of the lake during May, 1989. By June 7, 1989, this fish moved to the inflow of Angling Lake. It remained in this general vicinity until the last tracking date, May 14, 1990.

DISCUSSION

There have been difficulties in quantifing the effects of hydroelectric development on sturgeon in the lower Nelson River (Swanson and Kansas 1987, Swanson et al. 1988, Swanson et al. 1990). Telemetry studies to date have not pin pointed spawning locations. Spawning has not been positively identified. No sturgeon under ten years old have been captured.

Test netting below the Long Spruce Generating Station (L.S.G.S.) revealed sturgeon congregating there, however small the numbers. Two females contained eggs but were not ripe enough to spawn in 1989. The small population, the lack of ripe females, and the presence of four spent and two ripe males among those captured suggests that we might have missed the spawning in 1989. In Wisconsin peak spawning periods generally last only one day, and only occasionally for 3-6 days (Kempinger 1988). Daily temperatures recorded during this study, however, indicate that if anything we may have been a day or two early. It is more likely that the small number of sturgeon captured and the high recapture rate reflect low overall population levels, or that fish spawn in a different area such as in the rapids downstream of the dam. Historically, before the construction of the Limestone coffer dam, sturgeon were seen in large numbers at the base of the L.S.G.S. (Bert Swenson, Manitoba Hydro, pers. comm.). Populations of sturgeon in the lower Nelson River seem to be declining or perhaps using habitat further downstream as more construction takes place on the river.

Previous studies indicated that the Angling Lake/River system was a refuge for lower Nelson River sturgeon and might be used as a spawning area (Swanson et al. 1988; Swanson et al. 1990). Evidence of young-of-the-year and/or juvenile sturgeon in Angling Lake and Angling River was not found in 1989, although sampling methods and timing were quite extensive. All types of habitat were sampled to examine all possible rearing areas. If sturgeon use the river or lake to spawn, it is possible that young-of-the-year sturgeon migrate down to the Nelson River after hatching. Kempinger (1988) and Czeskleba et al. (1985) report downstream drifting of larval sturgeon after hatching. Observed and recorded flows on the Angling River are highest when temperatures are suitable for sturgeon spawning, therefore the flushing of larvae into the Nelson River is quite possible. It is also possible that sturgeon using the Angling Lake/River system spawn only at the mouth of the Angling River. In the Kenogomi River in Ontario, young sturgeon were captured primarily at the mouths of creeks flowing into the river (Ecologistics Limited 1988). Swanson and Kansas (1987) captured juvenile sturgeon (10-12 years old) at the mouth of the Angling River in 1986. As well, the 1989-90 telemetry study followed a radio-tagged sturgeon moving out of Angling Lake to the mouth of the Angling River in spring, perhaps to spawn. Still, the absence of young-of-the-year and juvenile sturgeon in the Angling Lake/River system is puzzling.

Radio-tagged sturgeon showed typical sedentary behaviour in Angling Lake, as reported in Swanson et al. (1990). Seven out of ten sturgeon remained in the deeper portions of the lake with

relatively little movement (1 km). Hay-Chmielewski (1987) notes similar movement patterns in Black Lake, Michigan with biotelemetry methods. Movements were correlated with food, substrate and depth. Sturgeon in Black Lake also preferred the deeper portions of the lake.

Two sturgeon in Angling Lake moved to the inflow area in the spring. Investigation of the habitat there did not reveal adequate spawning habitat (high water velocities, boulders and gravel), therefore it is believed the movements were for forraging purposes, and/or perhaps as a result of warmer water temperatures.

Radio tagged sturgeon 49.608 Mhz was the only fish to leave the lake and the river. The time of year and availability of spawning habitat at the mouth of the Angling River suggests that this may have been a spawning migration. The subsequent movement down the Nelson River to overwinter has been documented for other radio-tagged sturgeon (Swanson et al. 1988).

After attempting to fill gaps in the life history information on sturgeon in the lower Nelson River in 1989, questions still remain. Spawning below the L.S.G.S. probably occurs, but to a small extent as suggested by the low number of sturgeon captured and observed. Angling Lake definitely serves as a refuge for lower Nelson River sturgeon, most likely for feeding and opportunistic migrations during spring high water. If sturgeon do spawn in Angling River the larvae are most likely washed downstream into the Nelson River. Previous studies on the Nelson River downstream of the Angling River did not sample for small fish, therefore young sturgeon would not have been caught (Swanson and Kansas 1987).

Failure to capture sturgeon under ten years old during the entire lower Nelson River sampling program (1986-1989) suggests that if spawning does occur and is successful it is insignificant. While the barrier that dams create to migrations is an obvious impact, the fluctuation in flows released from reservoirs is less conspicuous but may have had devastating effects on sturgeon reproduction (Swanson et al. 1990).

CONCLUSIONS

1. Sturgeon appear to spawn below the L.S.G.S., but not in large numbers.

2. No young-of-the-year or juvenile sturgeon were caught in Angling Lake or Angling River. If sturgeon spawn in this system they probably do so in the lower reaches of the river and fry are flushed down to the Nelson River.

3. Angling Lake serves as a refuge from the Nelson River providing a stable environment with a suitable forage base. Radio-tagged sturgeon almost all remained sedentary in Angling Lake. One sturgeon moved out of Angling Lake to the mouth of the Angling River in the spring, perhaps to spawn.

RECOMMENDATIONS

1. Studies should be done to test for sturgeon spawning below the newly created Limestone G.S. to assess numbers of sturgeon and habitat chosen to spawn in.

2. A two-way fish fence should be installed and monitored in the mouth of the Angling River to detect sturgeon spawning migrations and/or spawning activities.

3. Existing radio-tagged sturgeon should continue to be monitored to gain further information on the use of the Angling River and Angling Lake by lower Nelson River sturgeon.

4. A feasibility study should be initiated to assess whether sturgeon spawning habitat below hydroelectric dams can be enhanced by improving substrate, water depth and flows.

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APPENDICES

APPENDIX 1

Tagging history of recaptured brook trout in the Nelson River study area.

1985-89 Brook Trout recapture summary

Tagnumber	Date	Location
48.371	23.09.85	SKY PILOT CK. @ MOUTH
	5.12.85	GILLAM TOWNSITE, NO INFO
48.399	20.09.85	LIMESTONE R. @ 5-MILE HOLE
	9.10.85	LIMESTONE R. @ 5-MILE HOLE, TURNED INTO C.O'S
48.454	12.09.85	LIMESTONE R. @ 5-MILE HOLE
	8.10.85	LIMESTONE R. @ 5-MILE HOLE (RELEASED)
49.110	21.07.89	9-MILE CK. MOUTH
	25.07.89	9-MILE CK. MOUTH
49.239	16.08.89	LIMESTONE R. BELOW HWG. CROSSING (CULVERTS)
	23.08.89	LIMESTONE R. (CULVERTS)
49.669	19.08.89	LIMESTONE R. @ 5-MILE HOLE
	19.09.89	9-MILE CK. ###TAG FOUND IN U/S TRAP####
49.890	21.07.89	9-MILE CK. MOUTH
	20.08.89	9-MILE CK. MOUTH
49.970	30.07.89	LIMESTONE R. MOUTH OF CN CK.
	23.08.89	LIMESTONE R. MOUTH OF CN CK.
1001006	3.08.87	CN CK.,1/2KM ABOVE CULVERTS
	8.09.87	CN CK. FOUND DEAD 100M BELOW FENCE #1
1001011	3.08.87	CN CK.,1/2KM ABOVE CULVERTS
	3.07.89	CN CK.
1001012	3.08.87	CN CK.,1/2KM ABOVE CULVERTS
	11.09.87	CN CK.
1001039	1.10.86	LIMESTONE R. @ 5-MILE HOLE
		-SUMMER-
1001043	28.08.86	LIMESTONE R. @ 5-MILE HOLE
	1.10.87	LIMESTONE R. @ 5-MILE HOLE NO OTHER INFO.
1001052	1.10.87	12-MILE CK.
	17.10.87	12-MILE CK.,100M ABOVE FENCE
	9.08.88	12-MILE CK. BESIDE AN UNMARKED CREEK
1001061	2.10.87	9-MILE CK.
	13.10.88	9-MILE CK.
1001063	3.10.87	9-MILE CK.,JUST ABOVE FENCE
	16.09.88	9-MILE CK.

I001065	3.10.87	9-MILE CK.,JUST ABOVE FENCE
	25.09.89	12-MILE CK.
I001066	3.10.87	9-MILE CK.
	19.08.88	LIMESTONE R.
I001075	3.06.87	MOONDANCE CK.
	29.08.87	MOONDANCE CK. @ MOUTH
I001080	9.09.86	LIMESTONE R. @ 5-MILE HOLE
	16.08.87	BIRD CK. @ MOUTH, R. BEARDY
I001104	3.10.87	9-MILE CK.
	29.09.88	9-MILE CK.
I001107	3.10.87	9-MILE CK.
	13.10.88	9-MILE CK.
I001110	3.10.87	9-MILE CK.
	25.09.88	9-MILE CK.
I001119	4.10.87	9-MILE CK.
	13.10.88	9-MILE CK.
I001172	12.10.87	WILSON CK.
	18.08.88	WILSON CK. F-PIT AREA
I001173	12.10.87	WILSON CK.
	4.07.88	WILSON CK.
I001174	12.10.87	WILSON CK.
	22.05.88	WILSON CK.
I001181	13.10.87	WILSON CK.
	10.07.88	SKY PILOT CK.
I001184	13.10.87	WILSON CK.
	7.09.89	WILSON CK.
	8.09.89	WILSON CK.
I001185	13.10.87	WILSON CK.
	13.10.88	WILSON CK.
I001190	14.10.87	WILSON CK.
	18.08.88	WILSON CK.
I001202	7.10.87	9-MILE CK.
	26.07.88	WILSON CK.
I001206	11.10.87	12-MILE CK.
	12.08.88	12-MILE CK. D/S OF CAMP

1001207	11.10.87	12-MILE CK.
	8.08.88	12-MILE CK. BELOW QUADRANT #4
	16.10.88	12-MILE CK. 100m U/S FROM FENCE
1001220	15.10.87	12-MILE CK.,100M ABOVE FENCE
	17.10.87	12-MILE CK.,100M ABOVE FENCE
	3.10.88	12-MILE CK. ABOVE DOWN TRAP
	27.09.89	12-MILE CK.
1001226	15.07.88	CN CK.HABITAT SEC.#1
	4.08.88	CN CK. HABITAT SEC#1
1001227	15.07.88	CN CK. HABITAT SEC.#3
	29.08.88	CN CK. POP. ESTIMATE SEC.
1001229	8.08.88	CN CK. POP. ESTIMATE SEC.
	10.08.88	CN CK. POP. ESTIMATE SEC.
1001230	8.08.88	CN CK. POP. ESTIMATE SEC.
	10.08.88	CN CK. POP. ESTIMATE SEC.
1001231	8.08.88	CN CK. POP. ESTIMATE SEC.
	10.08.88	CN CK. POP. ESTIMATE SEC.
1001236	31.08.88	CN CK. MOUTH
	23.08.89	LIMESTONE R. MOUTH OF CN CK.
1001237	16.08.89	LIMESTONE R. BELOW HWG. CROSSING (CULVERTS)
	23.08.89	LIMESTONE R. (CULVERTS)
1001248	4.08.88	CN CK.HABITAT SEC.#1
	21.08.89	CN CK. POP. ESTIMATE SEC.
1001272	26.09.88	WILSON CK.
	27.05.89	WILSON CK.
1001298	16.09.88	9-MILE CK.
	29.09.88	12-MILE CK.
1001312	14.10.88	LIMESTONE R. @ 5-MILE HOLE
	21.07.89	BIRD CK.
1001316	16.08.89	LIMESTONE R. BELOW HWG. CROSSING (CULVERTS)
	23.08.89	LIMESTONE R. (CULVERTS)
1001426	9.08.87	LIMESTONE R.,NEAR MOUTH OF CN CK.
	26.09.87	9-MILE CK.
	30.08.88	CN CK. MOUTH
1001433	6.09.87	MOONDANCE CK.
	23.09.87	MOONDANCE CK.
1001439	10.09.87	MOONDANCE CK. ###ALIAS 49-117###
	27.09.87	LIMESTONE R. @ 5-MILE HOLE

1001441	11.09.87	MOONDANCE CK.
	22.09.87	MOONDANCE CK.
1001478	2.10.87	WILSON CK.
	3.10.87	WILSON CK.
	14.10.87	WILSON CK.
1001509	1.08.87	LIMESTONE R.,NEAR MOUTH OF CN CK.
	30.08.88	CN CK. MOUTH
1001510	13.08.87	9-MILE CK. @ MOUTH
	16.10.88	12-MILE CK. 100m U/S FROM FENCE
1001512	17.08.87	9-MILE CK.,15M ABOVE FENCE
	29.08.87	9-MILE CK.
1001515	28.08.87	9-MILE CK. @ MOUTH
	13.09.87	9-MILE CK.
	20.09.87	9-MILE CK.
1001517	28.08.87	9-MILE CK.,10M ABOVE FENCE
	29.08.87	9-MILE CK.
1001519	9.09.87	9-MILE CK.,15M ABOVE FENCE
	11.10.87	9-MILE CK.,15M ABOVE FENCE,RELEASED DOWNSTREAM
1001520	10.09.87	12-MILE CK.,10M ABOVE FENCE
	23.09.87	12-MILE CK.
1001524	12.09.87	9-MILE CK.
	8.10.87	9-MILE CK.
1001534	9.09.89	9-MILE CK.
	9.09.89	9-MILE CK.
1001536	9.09.89	9-MILE CK.
	11.09.89	9-MILE CK.
	9.10.89	LIMESTONE R. @ 5-MILE HOLE
1001537	10.09.89	9-MILE CK.
	5.10.89	9-MILE CK.
1001544	19.09.89	9-MILE CK.
	19.09.89	9-MILE CK.
1001599	9.10.89	9-MILE CK.
	10.10.89	9-MILE CK.
1001611	4.10.89	9-MILE CK.
	7.10.89	9-MILE CK.
1001612	5.10.89	9-MILE CK.
	5.10.89	9-MILE CK.

I001613(14)	5.10.89	9-MILE CK.
	6.10.89	9-MILE CK.
I001618(19)	6.10.89	9-MILE CK.
	6.10.89	9-MILE CK.
I001620(21)	6.10.89	9-MILE CK.
	7.10.89	9-MILE CK.
I001633	25.09.89	9-MILE CK.
	9.10.89	9-MILE CK.
I001636	1.10.89	9-MILE CK.
	9.10.89	9-MILE CK.
	9.10.89	9-MILE CK. THERMOGRAPH POOL
I001637	1.10.89	9-MILE CK.
	5.10.89	9-MILE CK.
I001645	2.10.89	9-MILE CK. POOL ABOVE FENCE
	9.10.89	9-MILE CK.
I001646	2.10.89	9-MILE CK. POOL ABOVE FENCE
	4.10.89	9-MILE CK.
I001660	7.09.86	9-MILE CK. SPAWNING POOL
	2.10.87	9-MILE CK.
I001661	7.09.86	LIMESTONE R. @ 5-MILE HOLE
	9.09.86	LIMESTONE R. @ 5-MILE HOLE
I001667	1.06.87	MOONDANCE CK.
	23.06.87	MOONDANCE CK. ABOVE FENCE
I001668	6.06.87	CN CK.
	9.06.87	CN CK.
	19.06.87	CN CK.,50M ABOVE MOUTH
I001669	4.06.87	CN CK.,100M UP FROM MOUTH
	19.06.87	CN CK.,125M UP FROM MOUTH
I001671	5.06.87	MOONDANCE CK.
	4.07.87	MOONDANCE CK.
	23.07.87	MOONDANCE CK. 300M ABOVE FENCE
I001714	27.09.86	WEIR R. SPAWNING POOL
	24.09.88	WEIR R. SPAWNING POOL
	29.09.88	WEIR R. SPAWN POOL ###RETAGGED I001308###
I001735	5.10.88	WILSON CK.
	23.05.89	WILSON CK. MOUTH
I001774	19.09.88	SKY PILOT CK.
	12.10.88	SKY PILOT CK.

I001801	16.09.88	9-MILE CK.
	12.10.89	9-MILE CK. THERMOGRAPH POOL
I001821	1.10.88	9-MILE CK. ABOVE DOWN TRAP
	21.07.89	9-MILE CK. MOUTH
	9.09.89	9-MILE CK.
I001826	10.09.87	9-MILE CK. @ MOUTH
	13.09.87	9-MILE CK.
	3.10.87	9-MILE CK.
	5.09.88	9-MILE CK.
I001832	13.09.87	9-MILE CK.
	13.09.87	9-MILE CK.
	2.10.87	9-MILE CK.
I001837	16.09.87	9-MILE CK.
	3.10.87	9-MILE CK.
I001839	20.09.87	9-MILE CK.
	30.09.88	9-MILE CK.
	22.07.89	9-MILE CK., MOUTH
I001843	26.09.87	9-MILE CK.
	2.10.87	9-MILE CK.
	16.10.87	9-MILE CK.
	13.10.88	9-MILE CK.
I001846	27.09.87	9-MILE CK.
	16.09.88	9-MILE CK.
I001850	18.09.87	9-MILE CK.
	2.10.87	9-MILE CK.
I001857	26.09.88	LIMESTONE R. @ 5-MILE HOLE
	19.08.89	LIMESTONE R. @ 5-MILE HOLE
I001905	1.10.88	9-MILE CK. ABOVE DOWN TRAP
	22.07.89	9-MILE CK., 2nd CK. ABOVE MOUTH
I001906	2.10.88	12-MILE CK. ABOVE DOWN TRAP
	16.09.89	12-MILE CK.
I001921	17.10.88	9-MILE CK. ABOVE DOWN TRAP
	21.07.89	9-MILE CK. MOUTH
I001931	13.10.88	9-MILE CK. ABOVE DOWN TRAP
	9.10.89	9-MILE CK. THERMOGRAPH POOL
I001950	25.09.88	9-MILE CK.
	26.09.88	9-MILE CK.
	28.09.88	9-MILE CK. BESIDE STAFF GAUGE
	1.10.88	9-MILE CK.

I001980	13.10.88	WILSON CK.
	9.09.89	SKY PILOT CK.
	11.09.89	SKY PILOT CK.
I001983	13.10.88	WILSON CK.
	21.05.89	WILSON CK. MOUTH
OR00456	14.07.85	MOONDANCE CK.
	14.09.87	MOONDANCE CK.
OR00458	14.07.85	MOONDANCE CK.
	9.08.85	MOONDANCE CK. 1KM UP
OR00459	14.07.85	MOONDANCE CK.
	23.05.87	MOONDANCE CK.
	26.05.87	MOONDANCE CK.
	3.07.87	MOONDANCE CK. 200M ABOVE FENCE
	6.07.87	MOONDANCE CK.
OR00461	14.07.85	MOONDANCE CK. @ MOUTH
	10.08.85	MOONDANCE CK. JUST UP MOUTH
OR00470	17.07.85	MOONDANCE CK. @ MOUTH
	10.08.85	MOONDANCE CK. @ MOUTH
OR00492	16.08.85	9-MILE CK. 1KM UP
	4.09.85	9-MILE CK. 1KM UP
	17.09.85	9-MILE CK. MOUTH
OR00493	16.08.85	9-MILE CK. 1KM UP
	3.09.85	9-MILE CK. 1KM UP
OR00496	16.08.85	9-MILE CK. 1KM UP
	4.09.85	9-MILE CK. 1KM UP
OR00497	16.08.85	9-MILE CK. 1KM UP
	4.09.85	9-MILE CK. 1KM UP
OR00499	16.08.85	9-MILE CK. 1KM UP
	3.09.85	9-MILE CK. 1KM UP
	4.09.85	9-MILE CK. 1KM UP
OR00500	16.08.85	9-MILE CK. 1KM UP
	3.09.85	9-MILE CK. 1KM UP
OR00507	2.09.85	9-MILE CK. MOUTH
	3.09.85	9-MILE CK. MOUTH
	17.09.85	9-MILE CK. MOUTH
OR00508	3.09.85	9-MILE CK. MOUTH
	4.09.85	9-MILE CK. MOUTH
	1.10.86	LIMESTONE R. @ 5-MILE HOLE
	16.08.87	9-MILE CK. R.BEARDY

DR00510	3.09.85	9-MILE CK. MOUTH
	16.09.85	9-MILE CK. MOUTH
	17.09.85	9-MILE CK. MOUTH
DR00511	3.09.85	9-MILE CK. 1KM UPSTREAM
	4.09.85	9-MILE CK. 1KM UPSTREAM
DR00512	3.09.85	9-MILE CK. 1KM UPSTREAM
	4.09.85	9-MILE CK. 1KM UPSTREAM
DR00514	3.09.85	9-MILE CK. 1KM UPSTREAM
	7.09.86	9-MILE CK. SPAWNING POOL
	27.09.87	9-MILE CK.
DR00515	3.09.85	9-MILE CK.1KM UPSTREAM
	4.09.85	9-MILE CK.1KM UPSTREAM
DR00516	3.09.85	9-MILE CK.1KM UPSTREAM
	29.07.87	9-MILE CK.
DR00518	3.09.85	9-MILE CK. MOUTH
	4.09.85	9-MILE CK. MOUTH
	17.09.85	9-MILE CK.@ MOUTH ,RETAGGED #DR00527 ##########
DR00522/23	4.09.85	9-MILE CK.1KM UPSTREAM
	27.09.86	9-MILE CK. SPAWNING POOL
DR00536	7.09.85	LIMESTONE R. 7 MILES UPSTREAM
	17.09.85	9-MILE CK. MOUTH
	17.09.87	9-MILE CK. R.BEARDY (GILLNET)
DR00545	9.09.85	BIRD CK. , BELOW CULVERTS
	1.08.87	LIMESTONE R.,@CN CK.####RETAGGED #1001502 #####
DR00553	9.09.85	LIMESTONE R. JUST BELOW CULVERTS
	14.10.85	LIMESTONE R. @ 5-MILE HOLE
DR00555	9.09.85	LIMESTONE R. IN CULVERTS
	14.10.85	LIMESTONE R. @ 5-MILE HOLE
DR00556	9.09.85	LIMESTONE R. IN CULVERTS
	14.10.85	LIMESTONE R. @ 5-MILE HOLE
DR00558	10.09.85	LIMESTONE R. 1 MILE UP FROM BIRD CK. MOUTH
	12.10.85	LIMESTONE R. @ 5-MILE HOLE
DR00559	10.09.85	LIMESTONE R. BELOW CULVERTS
	14.10.85	LIMESTONE R. @ 5-MILE HOLE
DR00576	19.06.87	MOONDANCE CK.
	3.07.87	MOONDANCE CK. 200M ABOVE FENCE
DR00577	19.06.87	MOONDANCE CK.
	1.07.87	MOONDANCE CK. 200M ABOVE FENCE

DR00586	23.06.87	MOONDANCE CK. 50M ABOVE FENCE
	3.07.87	MOONDANCE CK.200M ABOVE FENCE
DR00587	23.06.87	MOONDANCE CK. 50M ABOVE FENCE
	23.07.87	MOONDANCE CK.200M ABOVE FENCE
DR00588	23.06.87	MOONDANCE CK.100M ABOVE FENCE
	25.06.87	MOONDANCE CK.
	3.07.87	MOONDANCE CK. 200M ABOVE FENCE
	30.08.87	MOONDANCE CK.
DR00591	24.06.87	CN CK.,1/2KM ABOVE CULVERTS
	21.07.89	BIRD CK.
DR00594	24.06.87	MOONDANCE CK.
	1.07.87	MOONDANCE CK.200M ABOVE FENCE
DR00599	4.07.87	MOONDANCE CK.
	22.07.87	MOONDANCE CK.
DR00600	6.07.87	MOONDANCE CK.
	5.09.87	MOONDANCE CK.
DR00629	21.09.89	WILSON CK.
	3.10.89	WILSON CK.
DR00652	16.09.89	SKY PILOT CK.
	10.10.89	SKY PILOT CK.
DR00676	9.06.89	CN CK.,30m BELOW DAM
	8.07.89	CN CK. BELOW DAM
DR00688	1.08.89	MOONDANCE CK. HABITAT SEC.#3
	17.08.89	MOONDANCE CK. HABITAT SEC.#3
DR00707	3.07.89	CN CK.,100m FROM LIMESTONE R.
	21.08.89	CN CK. POP. ESTIMATE SEC.
DR00717	14.08.89	SKY PILOT CK. SPAWNING POOL
	18.10.89	SKY PILOT CK.
DR00801	14.09.85	SKY PILOT CK. @ AA POOL
	19.09.85	SKY PILOT CK. @ AA POOL
DR00803	1.10.86	LIMESTONE R. @ 5-MILE HOLE
	13.09.87	9-MILE CK. ###RETAGGED I001820###
DR00808	27.05.87	CN CK.
	19.06.87	CN CK.,125M UP FROM MOUTH
DR00822	22.06.87	MOONDANCE CK.
	3.07.87	MOONDANCE CK. 200M ABOVE FENCE
	29.08.87	MOONDANCE CK.
	7.09.87	MOONDANCE CK.

OR00823	21.06.87	MOONDANCE CK.
	3.07.87	MOONDANCE CK. 300M ABOVE FENCE
OR00827	20.08.85	SKY PILOT CK. 800M DOWN FROM AA POOL
	14.09.85	SKY PILOT CK. AA POOL
OR00836	22.08.85	SKY PILOT CK.
	17.09.85	SKY PILOT CK. AA POOL
	22.09.85	SKY PILOT CK. AA POOL
OR00838	22.08.85	SKY PILOT CK. 800M DOWN FROM AA POOL
	17.09.85	SKY PILOT CK. AA POOL
	19.09.85	SKY PILOT CK. AA POOL
OR00851	14.09.85	SKY PILOT CK. AA POOL
	17.09.85	SKY PILOT CK. AA POOL
OR00852	14.09.85	SKY PILOT CK. AA POOL
	17.09.85	SKY PILOT CK. AA POOL
OR00853	14.09.85	SKY PILOT CK. AA POOL
	17.09.85	SKY PILOT CK. AA POOL
OR00885	19.08.85	SKY PILOT CK.800M DOWN FROM AA POOL
	16.09.85	SKY PILOT CK. AA POOL
OR00892	15.08.85	SKY PILOT CK. AA POOL
	24.09.85	SKY PILOT CK. MOUTH RADIO TRANS 48.96188888
OR00977	13.10.88	WILSON CK.
	31.05.89	WILSON CK.
OR00996	15.10.88	WILSON CK.
	2.06.89	WILSON CK.
RRTS04674	12.10.89	SKY PILOT CK.
	18.10.89	SKY PILOT CK.
RRTS04745	7.10.89	SKY PILOT CK.
	15.10.89	SKY PILOT CK.
UMI00572	31.08.87	MOONDANCE CK.
	22.09.87	MOONDANCE CK.
UMI00756	16.09.85	SKY PILOT CK. AA POOL
	17.09.85	SKY PILOT CK. AA POOL
UMI00758	16.09.85	SKY PILOT CK. AA POOL
	17.09.85	SKY PILOT CK. AA POOL
UMI00760	17.09.85	SKY PILOT CK. AA POOL
	22.09.85	SKY PILOT CK. AA POOL

UMI00771	17.09.85	SKY PILOT CK. AA POOL
	18.09.85	SKY PILOT CK. AA POOL
UMI00773	17.09.85	SKY PILOT CK. AA POOL
	19.09.85	SKY PILOT CK. AA POOL
UMI00775	17.09.85	SKY PILOT CK. AA POOL
	19.09.85	SKY PILOT CK. AA POOL
UMI00812	7.07.87	MOONDANCE CK.100M ABOVE FENCE
	8.09.87	MOONDANCE CK.

Appendix 2. Parasites found in three sturgeon from below the L.S.G.S. in June, 1989, as well as the length, weight, sex, age and stomach contents of each fish.

Fish Number	Length (mm)	Weight (gm)	Sex	Age	Parasites	Stomach contents
0174	1120	10,000	F	39	CR, TR	mayflies, sculpins
X827	1070	8,250	M	31	SP, CR, TR	mayflies, sculpins
0096	995	5,500	M	19	SP, CR, PO	crayfish

Key to parasites and locations

CR = Crepidostomum lintoni (intestine) trematode
*PO = Pomphorhynchus bulbocolli (intestine) spiny-headed worm
SP = Spinitectus gracilis acipenseri (crop) nematode
TR = Truttaedacnitis clitellarius (intestine) nematode

*denotes new host record for lake sturgeon

Appendix 3. Parasites found in three sturgeon from Angling Lake in July 1989, as well as the length, weight, sex, age and stomach contents of each fish.

Fish Number	Length (mm)	Weight (gm)	Sex	Age	Parasites	Stomach Contents
AL-1	1145	8,600	F	-	SP, CR, PO, DCL	gastropods
AL-2	913	3,700	F	-	SP, CR, PO, DCL	crayfish
AL-3	1090	8,500	M	-	CR, TR, PO, SP	gastropods

Key to parasites and locations

CR = Crepidostomum lintoni (trematode), intestine
DCL = Diclybothrium armatum (cestode), gills
*PO = Pomphorhynchus bulibocolli (spiny-headed worm), intestine
SP = Spinitectus gracillis acipenseri (nematode), crop
TR = Truttaedacnitis clitellarius (nematode), intestine

*denotes new host record for lake sturgeon

APPENDIX 4

Summary of data not previously reported for species other than brook trout and lake sturgeon; 1987-1989 lower Nelson River Studies.

INTRODUCTION

Since 1985, the Fisheries Branch has conducted studies in the Nelson River system to gather information on species composition and habitat use where hydroelectric development has occurred and may potentially occur. Data collected during those general inventory studies has been reported for all species, in yearly reports.

In addition to the general inventory, studies have been conducted which focus on brook trout and lake sturgeon. These species are of particular importance in the Nelson River system as they are Heritage Species. The brook trout also provide a trophy angling fishery. Recent reports of studies focused on these two species have not included incidentally collected data on other species.

This appendix presents a summary of those data not previously reported. The data were collected between 1987 and 1989, during electrofishing and fish fence studies of brook trout. Catches of brook trout have been reported previously and are not included in this appendix. For additional information on the 1987 studies refer to Swanson et al. (1988), on the 1988 studies refer to Swanson et al. (1990), and on the 1989 studies refer to the monitoring chapter of this report.

METHODS

Electrofishing

All electrofishing was conducted using a Smith-Root model 11A back-pack electrofisher carried by one person. A second person accompanied the electrofisher with a dip net, and a third person recorded data. Electrofishing was conducted in 100-m long sections. A seine net was installed at the downstream end of the section to prevent loss of fish downstream. The section was electrofished from the upstream end down to the net three times, consecutively. If portions of a section could not be sampled they were recorded to allow accurate determination of area sampled.

In 1987, electrofishing was conducted in the 15 sections established in 1986 on Moondance, Beaver, Swift, Tiny and Goose creeks (Figure 1) (Swanson and Kansas 1987). In addition, three electrofishing sections were established on CN Creek in 1987 (Figure 1), however electrofishing was not conducted in Section 1 since the water was stagnant and visibility was low (Swanson et al. 1988). Moondance, Beaver and CN creeks were sampled between August 14 and 26 in 1987, while Goose, Tiny and Swift creeks were sampled between September 13 and 14.

In 1988, all of those sections studied in 1987 were again electrofished. In addition, three new sections were established in each of Brooks and 15 creeks (Figure 1) (Swanson et al. 1990). Electrofishing was conducted in each creek on two occasions in 1988: July 15-25 and August 4-14. Each section was sampled in each period, except 15 Creek Section 1 which was only sampled

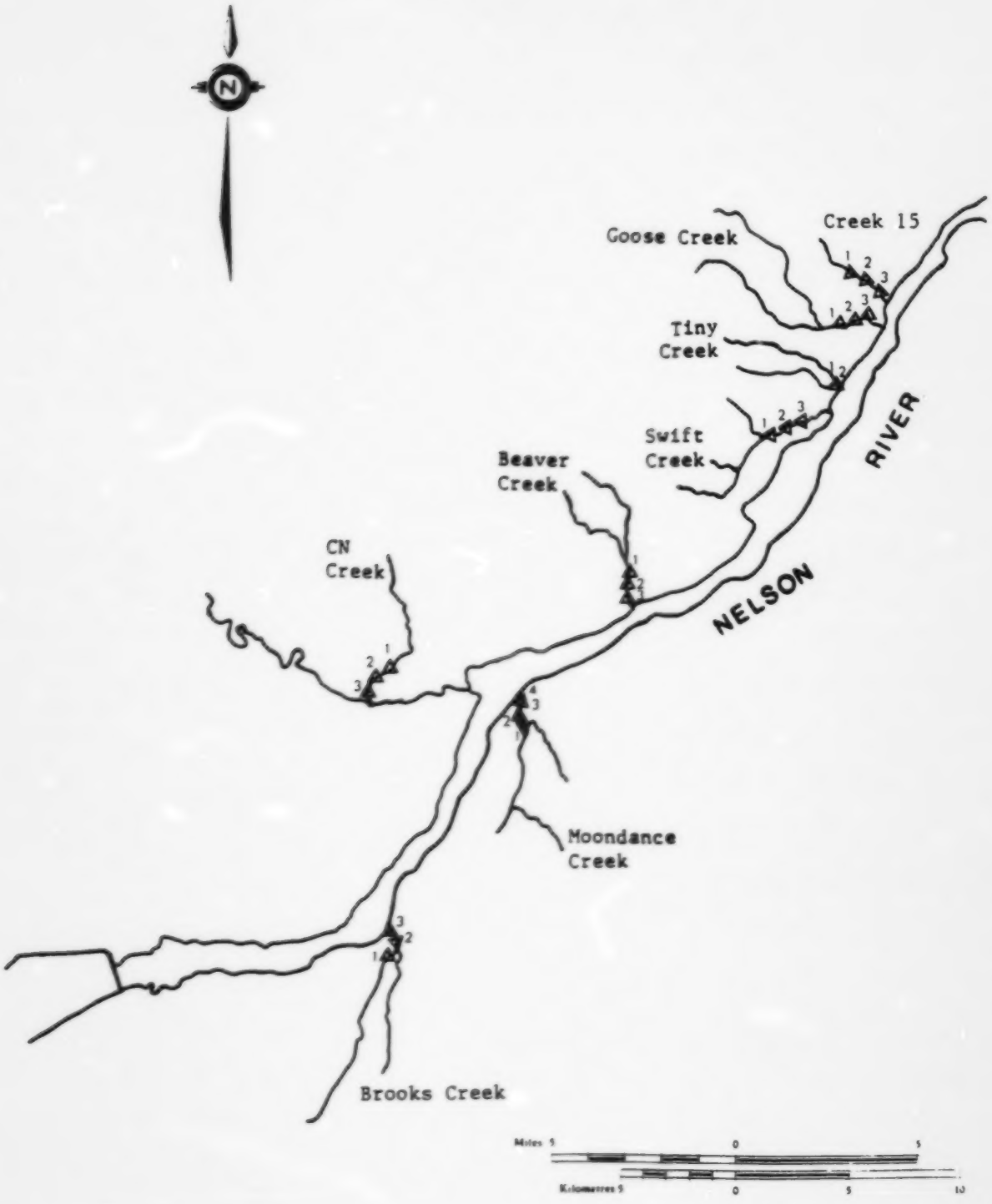

Figure 1. Locations of electrofishing sites, 1987-1989.

during the August period.

In 1989, electrofishing was conducted in all previously sampled streams, except Brooks Creek. Only the upstream two sections (1 & 2) in Swift Creek were sampled because the downstream section (3) was dry. Electrofishing was conducted between August 10 and 15 on all streams except Moondance Creek. Moondance Creek was electrofished on August 1-2, and again on August 17-18, before and after a stream crossing was constructed over the creek. It was thought that some change in numbers of brook trout present might occur due to construction of the crossing.

Fish Fences

Two-directional fish fences were installed and operated on tributaries to the Nelson and Limestone rivers in 1987, 1988 and 1989. In 1987, fences were installed in some streams in spring to monitor emigration of juvenile brook trout, and in other streams in fall to monitor brook trout spawning migrations. In subsequent years fences were installed only in fall to monitor spawning migrations. Spring fences were constructed of 7-mm mesh (stretched measure) while fall fences were constructed of larger mesh (2.5-mm and larger). Consequently, small species such as minnows were sampled only in the small-mesh fences installed in spring of 1987.

Traps in the fences were checked twice daily, wherever possible, to sample and release captured fish. The number of each species captured was recorded according to direction of travel, i.e. upstream or downstream trap. Fences were examined on each visit to remove accumulated debris, and repair or reinforce where

necessary.

One small-mesh fence was installed in each of Beaver, CN, and Moondance creeks and operated from May 14 to October 14, 1987 (Figure 2) (Swanson et al. 1988). In CN Creek, a second small-mesh fence (#2) was installed and operated downstream of the first, from July 23 to September 22, 1987.

In fall of 1987, large-mesh fences were constructed on Wilson, Sky Pilot, 9-Mile and 12-Mile creeks (Figure 2) (Swanson et al. 1988). All fences were in place by August 13 and were operated until October 20. Results of 1987 fall fence operation indicated that monitoring in August was unnecessary for studies of spawning brook trout, and data could be obtained during September and October.

As a result, in 1988 fences were operated between September 2 and October 20. Fences were again installed in the four streams monitored in 1987, and also in Leslie Creek (Figure 2) (Swanson et al 1990).

In 1989, as in the previous two years, fall fences were installed in Wilson, Sky Pilot, 9-Mile, and 12-Mile creeks. A fence was not installed in Leslie Creek. The fences were operated from September 7 until ice conditions began to hamper fence efficiency, October 16-18.

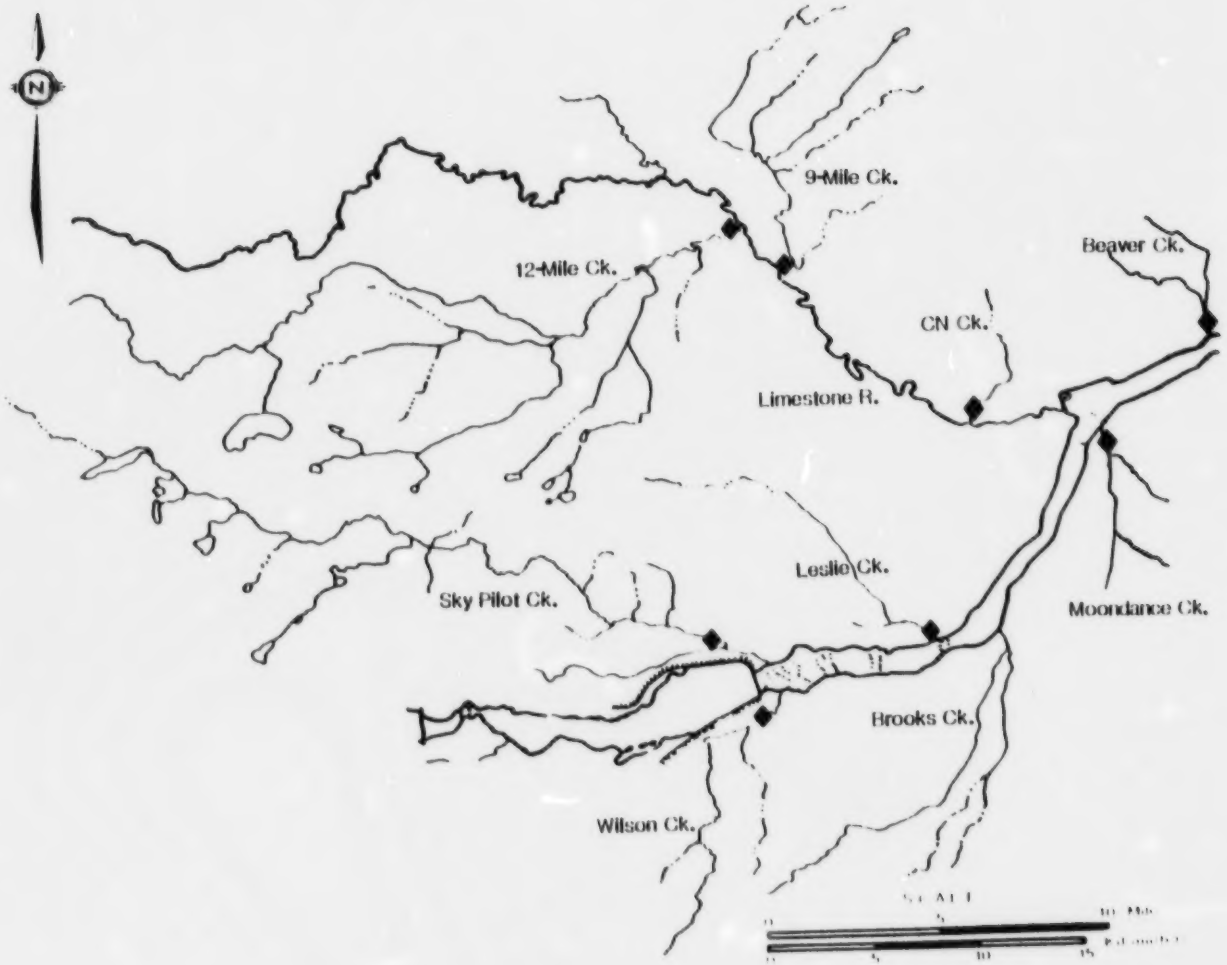

Figure 2. Locations of fish fences, 1987-1989.

RESULTS AND DISCUSSION

Electrofishing

Data are presented in one table for each stream. Each table contains, by sample section and date, the area sampled, seconds of electrofishing, and number of each species captured. Brook trout are not included.

Results of electrofishing in Moondance Creek are presented in Table 1. In each year slimy sculpin and white sucker were the most frequently captured species. Species composition in each section was similar. Burbot and cisco were captured only in the two downstream sections, where migration from the Nelson River was possible. Catches of slimy sculpin and white sucker were notably greater immediately following construction of the Moondance Creek road crossing in 1989. It is possible that these fish were displaced downstream into sections 3 and 4 by construction of the crossing upstream.

Table 2 contains data from electrofishing in Beaver Creek. Since Beaver Creek is a much smaller stream, and provides less stable and less diverse habitat, it supports fewer species than larger streams such as Moondance Creek.

Table 3 summarizes results of electrofishing in Swift Creek. No fish were captured in 1987 due to extremely high discharge caused by rain. Visibility was limited, and high velocities likely swept stunned fish downstream. Electrofishing results in 1988 indicate that this stream is most suitable for brook stickleback. Only sections 1 and 2 were sampled in 1989; section 3, the

Table 1. Summary of electrofishing catch and effort in study sections of Moondance Creek, 1987-89. Brook trout have been reported elsewhere.

Section	Date	Electrofishing Effort		Catch[a]									
		Area (m2)	Seconds	SLSC	LNDC	WTSK	LNSK	BKST	JNDT	PLDC	FNDC	BURB	CISC
	1987												
1	Aug 21	670	250	2	-	-	-	-	-	-	-	-	-
2	Aug 18	544	2199	11	1	-	4	1	1	3	-	-	-
3	Aug 15	522	389	5	-	-	4	-	1	-	-	-	-
4	Aug 14	660	450	6	-	9	-	-	-	-	-	-	-
	1988												
1	Jul 19	694	1739	11	-	11	-	6	1	1	2	-	-
	Aug 6	776	1617	4	-	21	2	8	2	-	-	-	-
2	Jul 19	735	1298	19	-	7	-	1	3	-	-	-	-
	Aug 6	889	1639	26	-	3	6	2	5	-	-	-	-
3	Jul 19	546	300	16	2	19	-	3	1	6	-	-	-
	Aug 6	569	1522	18	-	5	3	3	4	-	-	-	-
4	Jul 19	716	1114	16	1	5	-	-	1	-	-	-	-
	Aug 6	728	1269	8	1	2	4	-	-	-	-	-	-
	1989												
1	Aug 2	633	1685	17	13	-	-	2	-	1	-	-	-
	Aug 18	601	991	-	-	13	-	-	-	-	-	-	-
2	Aug 2	656	2348	26	20	10	-	-	-	-	-	-	-
	Aug 18	611	1216	10	-	17	-	3	11	-	-	-	-
3	Aug 1	515	3054	11	1	-	9	1	-	-	-	-	-
	Aug 17	503	1905	74	-	39	-	3	-	-	-	1	1
4	Aug 1	688	1875	49	2	-	6	2	-	-	-	1	-
	Aug 17	584	1674	81	-	12	-	-	-	-	-	2	1

a SLSC = slimy sculpin, LNDC = longnose dace, WTSK = white sucker, LNSK = longnose sucker, BKST = brook stickleback, JNDT =johnny darter, PLDC = pearl dace, FNDC = finescale dace, BURB = burbot, CISC = cisco

Table 2. Summary of electrofishing catch and effort in study sections of Beaver Creek, 1987-89. Brook trout have been reported elsewhere.

Section	Date	Electrofishing Effort		Catch[a]			
		Area (m2)	Seconds	SLSC	WTSK	BKST	BURB
	1987						
1	Aug 22	440	970	2	-	9	-
2	Aug 23	320	759	-	-	-	-
3	Aug 23	320	700	-	-	3	-
	1988						
1	Jul 18	573	746	5	-	7	-
	Aug 7	409	692	1	-	2	-
2	Jul 18	360	282	-	-	-	-
	Aug 7	257	326	-	-	-	-
3	Jul 18	370	361	2	-	-	-
	Aug 7	264	558	1	-	-	-
	1989						
1	Aug 11	315	645	-	-	14	-
2	Aug 11	308	647	1	1	-	-
3	Aug 11	212	638	2	1	-	1

a SLSC = slimy sculpin, WTSK = white sucker, BKST = brook stickleback, BURB = burbot

Table 3. Summary of electrofishing catch and effort in study sections of Swift Creek, 1987-89. Brook trout have been reported elsewhere.

		Electrofishing Effort		Catch[a]							
Section	Date	Area (m2)	Seconds	SLSC	LNDC	WTSK	LNSK	BKST	PLDC	FNDC	BURB
	1987										
1	Sep 14	603	375	-	-	-	-	-	-	-	-
2	Sep 14	830	655	-	-	-	-	-	-	-	-
3	Sep 14	730	595	-	-	-	-	-	-	-	-
	1988										
1	Jul 22	686	1237	-	1	-	-	14	1	-	1
	Aug 11	594	1058	1	3	3	-	3	-	-	-
2	Jul 22	587	1151	1	1	2	7	39	-	-	1
	Aug 11	680	1517	3	-	-	-	15	1	2	-
3	Jul 22	658	1518	2	3	4	-	41	-	-	-
	Aug 11	654	1523	-	1	3	3	4	-	-	-
	1989										
1	Aug 15	529	647	-	-	19	-	2	-	-	-
2	Aug 15	344	456	-	-	62	-	2	-	-	-

a SLSC = slimy sculpin, LNDC = longnose dace, WTSK = white sucker, LNSK = longnose sucker, BKST = brook stickleback, PLDC = pearl dace, FNDC = finescale dace, BURB = burbot

downstream section, was completely dry. The large numbers of white sucker captured in 1989 were primarily young of the year.

Results of electrofishing in Tiny Creek are presented in Table 4. Few species have been captured in this small stream. Brook stickleback were quite abundant in 1988. In 1987, high discharge prevented capture of any fish.

Goose Creek harbours a greater number of fish species than the nearby smaller streams such as Tiny and Swift creeks (Table 5). Slimy sculpin and longnose dace were the most common species in both 1988 and 1989, with the exception of a large concentration of pearl dace in the upstream section in 1989. The upstream section, which contains deeper, wider areas than the two downstream sections, provides more diverse habitat and therefore supports a greater number of species. As in Swift and Tiny creeks, at the time of sampling in 1987 discharge was unusually high and prevented capture of any fish.

Few species other than brook trout have been captured in CN Creek (Table 6). Slimy sculpin were most consistently captured, even in low-water conditions as experienced in 1987.

Despite the small size of Fifteen Creek, several fish species were captured during electrofishing in both 1988 and 1989 (Table 7). None of these species was particularly abundant.

In the one year when Brooks Creek was electrofished, six fish species were captured (Table 8). Most were found in the two downstream sections where habitat was deeper and more diverse than in the upstream section.

Table 4. Summary of electrofishing catch and effort in study sections of Tiny Creek, 1987-89. Brook trout have been reported elsewhere.

Section	Date	Electrofishing Effort		Catch[a]	
		Area (m2)	Seconds	SLSC	BKST
	1987				
1	Sep 14	315	301	-	-
2	Sep 14	260	472	-	-
	1988				
1	Jul 23	175	300	-	-
	Aug 12	99	449	-	23
2	Jul 23	195	33	-	2
	Aug 12	190	693	1	13
	1989				
1	Aug 13	192	430	1	-
2	Aug 13	231	474	-	-

a SLSC = slimy sculpin, BKST = brook stickleback

Table 5. Summary of electrofishing catch and effort in study sections of Goose Creek, 1987-89. Brook trout have been reported elsewhere.

		Electrofishing Effort		Catch[a]							
Section	Date	Area (m2)	Seconds	SLSC	LNDC	WTSK	LNSK	BKST	PLDC	FNDC	BURB
	1987										
1	Sep 13	660	291	-	-	-	-	-	-	-	-
2	Sep 13	490	401	-	-	-	-	-	-	-	-
3	Sep 13	680	850	-	-	-	-	-	-	-	-
	1988										
1	Jul 21	527	1317	-	2	1	-	3	3	3	1
	Aug 14	536	1960	-	3	2	3	3	-	17	-
2	Jul 21	384	1155	2	2	-	1	-	-	-	-
	Aug 14	387	964	2	5	-	1	-	-	-	-
3	Jul 21	714	997	-	2	-	-	-	-	-	-
	Aug 14	614	1257	3	-	-	2	-	-	-	-
	1989										
1	Aug 12	586	1389	2	2	-	1	5	101	-	-
2	Aug 12	440	1141	15	7	4	-	-	1	-	-
3	Aug 12	490	1249	7	10	3	-	2	-	-	-

a SLSC = slimy sculpin, LNDC = longnose dace, WTSK = white sucker, LNSK = longnose sucker, BKST = brook stickleback, PLDC = pearl dace, FNDC = finescale dace, BURB = burbot

Table 6. Summary of electrofishing catch and effort in study sections of CN Creek, 1987-89. Brook trout have been reported elsewhere.

Section	Date	Electrofishing Effort		Catch[a]			
		Area (m2)	Seconds	SLSC	LNDC	BKST	BURB
	1987						
2	Aug 26	220	1084	6	-	-	-
3	Aug 25	195	653	1	-	-	-
	1988						
1	Jul 15	731	810	-	-	-	-
	Aug 4	265	879	-	-	2	-
2	Jul 15	197	645	-	-	-	1
	Aug 4	141	555	5	2	-	1
3	Jul 15	270	634	1	-	-	-
	Aug 4	192	802	6	-	-	_
	1989						
1	Aug 10	235	818	-	-	29	_
2	Aug 10	188	426	12	-	-	_
3	Aug 10	161	763	5	-	-	_

a SLSC = slimy sculpin, LNDC = longnose dace, BKST = brook stickleback, BURB = burbot

Table 7. Summary of electrofishing catch and effort in study sections of Fifteen Creek, 1988-89. Brook trout have been reported elsewhere.

Section	Date	Electrofishing Effort		Catch[a]							
		Area (m2)	Seconds	SLSC	LNDC	WTSK	LNSK	BKST	PLDC	FNDC	BURB
	1988										
1	Aug 13	160	674	-	-	-	-	2	-	8	1
2	Jul 25	173	527	-	-	-	-	-	-	-	-
	Aug 13	179	798	-	1	1	-	1	-	8	-
3	Jul 25	257	877	-	3	-	-	1	1	-	-
	Aug 13	282	769	-	7	-	2	1	-	-	1
	1989										
1	Aug 16	146	758	1	-	1	-	-	11	-	-
2	Aug 16	143	411	1	-	-	-	1	-	-	-
3	Aug 16	312	922	1	1	-	-	1	2	-	-

a SLSC = slimy sculpin, LNDC = longnose dace, WTSK = white sucker, LNSK = longnose sucker, BKST = brook stickleback, PLDC = pearl dace, FNDC = finescale dace, BURB = burbot

Table 8. Summary of electrofishing catch and effort in study sections of Brooks Creek, 1988. Brook trout have been reported elsewhere.

Section	Date	Electrofishing Effort		Catch[a]					
		Area (m2)	Seconds	SLSC	LNDC	WTSK	LNSK	BKST	FNDC
	1988								
1	Jul 17	501	498	-	-	-	-	1	-
	Aug 5	505	659	-	1	-	1	3	-
2	Jul 17	600	556	1	-	1	-	-	-
	Aug 5	605	821	9	-	1	-	3	-
3	Jul 17	627	778	12	1	4	-	1	-
	Aug 5	627	705	4	-	1	-	-	1

a SLSC = slimy sculpin, LNDC = longnose dace, WTSK = white sucker, LNSK = longnose sucker, BKST = brook stickleback, FNDC = finescale dace

Fish Fences

The small-mesh fences installed in spring of 1987 provide information on small as well as large fish species in CN, Beaver and Moondance creeks (Table 9). Several species not found during electrofishing were captured in these fences. In Beaver Creek these species included northern pike, blacknose dace, longnose dace, pearl dace and johnny darter. In CN Creek the additional species were longnose sucker, white sucker, silver lamprey and blacknose dace. In Moondance Creek, northern pike and blacknose dace were captured in fences but not while electrofishing.

In Beaver and CN creeks the only notable movement of fish during fence operation consisted of sculpins moving downstream in late summer and fall. From mid-August onward an almost steady movement of sculpins, both young-of-the-year and larger, occurred through downstream fences. Before mid-August very few sculpins were captured moving downstream in either creek.

In Moondance Creek, no migration of sculpins was detected. However, the downstream fence on Moondance Creek was not efficient and allowed some fish to pass undetected (Swanson et al. 1988). Perhaps migrating sculpins were able to travel through this fence and were therefore not captured. Significant upstream and downstream migrations of longnose suckers and white suckers were recorded in Moondance Creek. The migration of longnose suckers occurred primarily between May 26 and June 7; most white suckers migrated upstream between May 26 and June 13. This movement was to spawning areas upstream of the fences. Most of the downstream movement of both sucker species occurred during, or just following,

Table 9. Summary of fish species captured in small-mesh fences in tributaries to the Limestone and Nelson rivers, 1987. Brook trout have been reported elsewhere.

Species	CN #1 1987		CN #2 1987		Moondance 1987		Beaver 1987	
	Up	Down	Up	Down	Up	Down	Up	Down
Northern Pike	-	-	-	-	1	-	17	7
Sucker sp.	1	-	-	-	2	6	11	10
Longnose Sucker	6	-	-	1	403	293	6	4
White Sucker	1	-	-	1	165	193	24	11
Burbot	1	-	-	-	-	-	-	2
Silver Lamprey	-	1	-	-	-	-	-	-
Dace sp.	1	-	-	-	-	1	1	-
Blacknose Dace	1	-	-	-	1	-	-	1
Longnose Dace	8	14	-	19	21	4	5	24
Pearl Dace	-	-	-	-	-	8	-	
Sculpin sp.	19	115	3	149	10	15	15	161
Slimy Sculpin	11	2	-	1	4	12	5	4
Stickleback	3	15	-	-	-	15	17	38
Brook Stickleback	-	1	-	-	-	10	3	9
Johnny Darter	-	-	-	-	-	1	-	-

the period of upstream migration as spawned-out fish returned to rearing areas.

Operation of large-mesh fish fences in fall selectively provided data on large species which move in fall. During the three years of fence operation on Sky Pilot Creek northern pike have consistently moved downstream in September and October (Table 10). The movement occurs over an extended period, 30 to 45 days. Generally, 1 to 10 individuals moved through the fence each day, however the movement may peak for several days with 10 to 30 individuals captured each day. These pike are primarily juveniles which have reared in Sky Pilot Creek during the summer. The movement is thought to be for locating suitable overwintering habitat in deeper water downstream, perhaps in the Nelson River. Juvenile pike undoubtedly move upstream into Sky Pilot Creek in spring and summer to find summer rearing habitat.

A similar downstream movement of juvenile white suckers occurred each fall in Sky Pilot Creek. Timing of movement coincided with movement of pike. The movement of suckers is also believed to be for locating suitable overwintering habitat.

In Wilson Creek, on the south side of the Nelson River, similar but smaller movements of northern pike and white suckers were recorded in fall of each year, 1987-89 (Table 10). As in Sky Pilot Creek these movements were prolonged through September and October, and were primarily juveniles moving to locate winter rearing habitat.

In Leslie Creek, few fish other than the brook trout previously reported (Swanson et al. 1990) were captured in the fall

Table 10. Summary of fish species captured in large-mesh fences in Limestone Forebay tributaries of the Nelson River, 1987-98. Brook trout have been reported elsewhere.

Species	Leslie				Sky Pilot						Wilson			
	1988		1987		1988		1989		1987		1988		1989	
	Up	Down	Up	Down	Up	Down	Up	Down	Up	Down	Up	Down	Up	Down
Northern Pike	-	-	19	182	11	166	11	329	3	104	1	109	3	59
Longnose Sucker	-	1	-	3	-	2	-	-	-	9	-	-	-	-
White Sucker	-	2	7	182	31	284	29	581	2	54	-	10	-	23
Burbot	-	-	1	-	-	4	-	-	-	-	-	-	-	-

fence operated in 1988 (Table 10).

Large-mesh fish fences constructed in tributaries to the Limestone River revealed movements similar to those detected in Nelson River tributaries. In both 9-Mile and 12-Mile creeks northern pike, primarily juveniles, move downstream past fences in fall (Table 11). The timing and pattern of movements is similar to that described for Nelson River tributaries. The movement is also believed to be for locating overwintering habitat. A significant downstream movement of white suckers occurs each fall in 12-Mile Creek, but not in 9-Mile Creek. As in Sky Pilot and Wilson creeks the suckers move downstream through September and October in a prolonged migration. The absence of these suckers, primarily juveniles, from 9-Mile Creek may be due to unavailability of summer rearing habitat in that stream.

SUMMARY

Electrofishing

Eleven fish species in addition to brook trout were captured in the electrofishing streams during 1987-89. Larger streams generally contained more stable and diverse habitat, and therefore harboured more species, than smaller streams. Species composition and total abundance varied with location of the sampling sections within a stream (upstream verses downstream) and was not consistent between streams. Suitability of sampling sections for fish was dependent upon many factors including size of the drainage basin, slope of the streambed, and the presence or absence of beaver dams.

Table 11. Summary of fish species captured in large-mesh fences in Limestone River tributaries, 1987-89. Brook trout have been reported elsewhere.

Species	9-Mile						12-Mile					
	1987		1988		1989		1987		1988		1989	
	Up	Down	Up	Down	Up	Down	Up	Down	Up	Down	Up	Down
Northern Pike	31	118	3	30	14	28	30	318	23	914	23	207
Sucker sp.	-	-	-	-	-	-	4	25	-	-	-	-
White Sucker	12	4	1	2	3	4	65	436	3	171	4	115
Burbot	1	-	-	1	-	2	-	-	-	-	-	1

Brook stickleback and slimy sculpin were present in all of the streams sampled, and are thought to use these streams for all stages of their life history. Other small species, including longnose dace, finescale dace, pearl dace and johnny darter occur only in the larger streams, which can provide suitable habitat for all life stages. Species such as white sucker and longnose sucker use some of these streams for spawning and rearing only. Burbot are present only as juveniles which migrate upstream from the Limestone and Nelson rivers to find suitable rearing habitat. Ciscoes were captured only in the downstream sections of the largest stream, Moondance Creek, and undoubtedly migrated in from the Nelson River.

Fish Fences

The operation of small-mesh fish fences throughout the openwater period in 1987 revealed the presence of species not found during electrofishing in Moondance, Beaver and CN creeks. The only notable movement of fishes in Beaver and CN creeks, other than brook trout as reported elsewhere, was the downstream movement of sculpins in late summer and fall. No movement of sculpins was apparent in Moondance Creek. Perhaps it does not occur, or perhaps the sculpins were able to evade the fence and continue downstream undetected. The downstream fence in Moondance Creek was found to be inefficient, allowing some fish to pass without entering the trap. Both longnose suckers and white suckers migrate into Moondance Creek to spawn in spring, and move back downstream to the Nelson River shortly after spawning.

Migrations of spring spawners, and movements of small species, were not detected where large-mesh fences were constructed in fall. White suckers and longnose suckers have been observed migrating into the larger streams such as Wilson and Sky Pilot creeks to spawn in spring. These streams must also contain a variety of small species such as those found where small-mesh fences were used in 1987. The only significant movements through fall fences in both Nelson River and Limestone River tributaries, other than the brook trout reported previously, were downstream movements of northern pike and white suckers. These consisted primarily of juveniles moving downstream to suitable overwintering habitat.